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A LABORATORY MANUAL
IN
GENERAL BIOLOGY

BY

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AND

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PREFACE

The laboratory exercises outlined in this manual are intended to accompany the use of the *Textbook of General Biology*, by James W. Mavor, one of the features of which is the possibility of a close correlation between textbook and laboratory work.

The manual is based on one which was developed for use in the course in General Biology at Union College and which has been used there for a number of years. An effort has been made to reduce to a minimum instructions and required drawings so that the student may spend as much of his time as possible in the actual observation of specimens. To this end printed outline drawings are provided for the student to complete, and questions to be answered and tables to be filled in have in many cases been substituted for required drawings.

It is not expected that all of the types included will be studied in any one course. The object has been to provide the instructor with a series of exercises which he can choose from, so that he may use the material which he deems best suited to his course or which is most readily available. In this way, too, the laboratory work may be varied from year to year.

The exercise entitled "A Survey of the Animal Kingdom" is somewhat of a departure in a laboratory outline of this type. We have found, however, that it creates a great deal of interest on the part of the students and fits in well at the end of the course when the various aspects of evolution are being discussed in the classroom. Material for this exercise is now readily obtainable from most of the supply houses and the preserved specimens can be kept from year to year. We have found it convenient to have small systematic collections made up containing specimens of most of the animals mentioned in this part of the outline, assigning one set to each student or each two students. Each specimen is sealed in a separate labeled container in such a way as to be easily examined, and the sets are arranged in separate drawers. In this way the material is available from year to year with comparatively little labor.

The pages may be separated at the perforations and bound in a loose leaf cover. This makes it possible for the student to hand in his work after each laboratory period. Additional work may be done on blank sheets and bound with those of the outline.

The senior author, James W. Mavor, is responsible for the plan, text, and general make up of the manual and for the separate sections with the exception of those on the Microscope, Paramecium, Cell Division, Bread Mold, Moss, Flower, Skeleton, Circulation, and the Survey of the Animal Kingdom in which Leonard B. Clark collaborated with him.

The authors wish to express their indebtedness to Dr. E. E. Dale for valuable suggestions and criticisms in the preparation and use, especially of the botanical portion, of the outline and to Mr. August Swyka for the illustrations.

James W. Mavor
Leonard B. Clark

Schenectady, N. Y.
August, 1936

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A LABORATORY MANUAL IN GENERAL BIOLOGY

I. GENERAL INSTRUCTIONS

1. Importance of Observation

Science is the study of things which can be seen and experienced with the senses. It has its foundation in observation. The greatest benefit which a student can derive from a course in a science is an understanding and appreciation of the scientific method as applied to the subject of the course. This he can do only by making his own observations and drawing his own conclusions. Apart from this everyone understands and remembers better the things which he has seen. Try to see as much in your specimen as you can and try to be certain of what you see. Cultivate independence. In case of a real difficulty consult the instructor, not your neighbor.

2. Notes

Much of this outline is in the form of questions to be answered by the student. In practically all cases the student will find a direct answer to the questions in studying his preparation. The matter is put in the form of questions to emphasize to the student that in biology as in any science the facts depend on observation and not on the authority of textbooks. It is the mental and physical processes by which the answers are obtained that is important for the student. Sometimes there is no one correct answer to a question, but accurate observation and clear thinking are always possible. Whether or not the student develops this, the most important of all attainments, depends largely on his own efforts.

3. Drawings

The object of making drawings is to learn how to see things. It is only when one attempts to draw an object that he really begins to see it, and it is only by drawing an object that one can tell whether he has really seen it. All drawings must be made *in the laboratory* and should be made with a hard, sharp pencil. Make your drawing directly from your own specimen. A clear outline is the first essential of a good drawing. Where an object shows more or less uniform detail over a large area, draw this detail for only a small portion, leaving it to be understood that the rest of the area is similar. Label drawings by ruling fine solid lines out toward the margin and writing the name of the structure on a horizontal line. Do not use any system of lettering or numbering. This is confusing and time consuming.

A title should accompany each drawing, specifying as clearly as possible the object drawn. To this should be added a statement of the magnification. If the drawing was made by viewing the object with the naked eye state how many times it has been magnified, if with the low power of the microscope indicate this by L.P., if with the high power by H.P.

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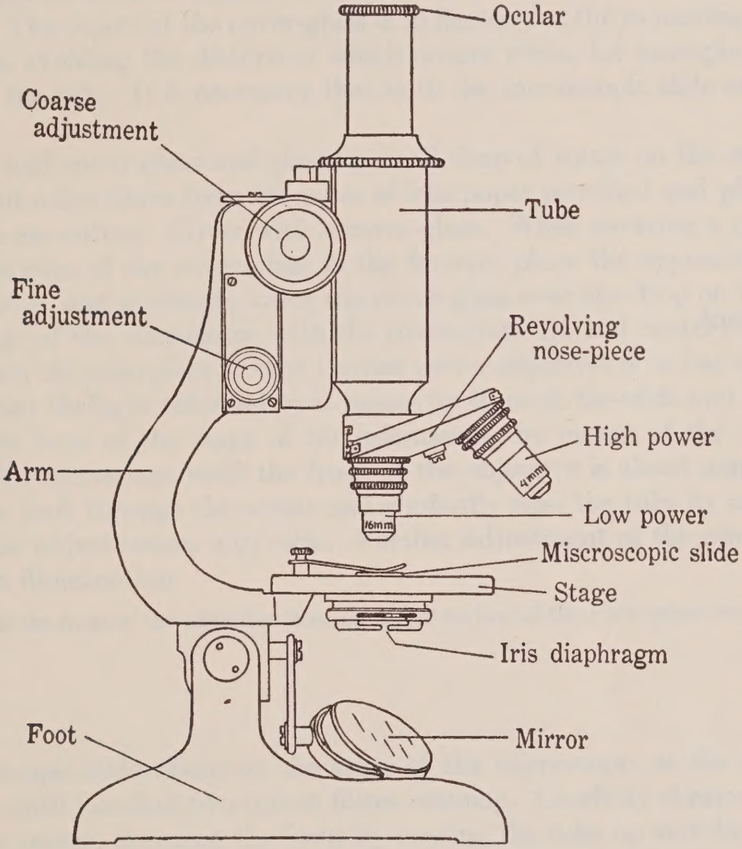
II. THE USE OF THE MICROSCOPE

Note. A microscope is a delicate scientific instrument. It should be handled with care and with due regard for the lenses and adjustments.

1. Parts of the Microscope

Identify the parts of your microscope by the aid of the labeled figure.



Ocular
Coarse adjustment
Tube
Fine adjustment
Revolving nose-piece
High power
Arm
Low power
Miscroscopic slide
Stage
Iris diaphragm
Foot
Mirror
16mm
4mm

I

A Compound Microscope

2. Functions of the Parts of the Microscope

State briefly the functions of each of the following parts:

Stage

Low power objective (16 mm. or 10 x)

High power objective (4 mm. or 43 x)

Revolving nose piece

Tube

Ocular

Coarse adjustment

Fine adjustment

Mirror

Iris diaphragm

3. Rules to Be Observed in Using the Microscope

The following rules should be adhered to when using the microscope.

1. Always find the object with the low power before using the high power.
2. Use the high power only to see details which cannot be seen with the low power and only on objects which are covered by a cover-glass.
3. When using the high power do not focus downward unless you know that there is ample space between the front of the lens and the cover-glass.
4. Always raise the high power objective before removing a slide.
5. Do not touch the lenses with anything except the special lens paper provided for the purpose.
6. To clean an objective or ocular, breathe on the surface of the glass and rub *lightly* with the lens paper. Use only fresh lens paper and use the same sheet only once. If the lens does not yield to this method of cleaning consult the instructor.

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4. EXERCISES ON THE USE OF THE MICROSCOPE

The compound microscope may be used for the examination of objects, either by transmitted light, when the light passes through the object, which must therefore be more or less transparent, or by reflected light, when the light is reflected from the object, of which the surface only is seen. In either case the object is usually placed on a piece of clear glass, 1 × 3 inches, called a *microscopic slide.* If the object is to be viewed by transmitted light it is usually immersed in a small quantity of liquid, such as a drop of water, and covered with another thinner piece of glass called a *cover-glass.* The object of the cover-glass is to flatten out the mounting fluid and provide a level surface, thus avoiding the distortion which occurs when, for example, one looks into a glass of water from the side. It is necessary that both the microscopic slide and the cover-glass be clean.

A. Clean a slide and cover-glass and place a small drop of water on the center of the slide. With forceps pull out a few fibres from the piece of lens paper provided and place in the drop of water. These fibres are cotton. Cover with a cover-glass. When covering a preparation with a cover-glass hold one edge of the cover-glass in the forceps, place the opposite edge on the slide on one side of the drop, and gradually lower the cover-glass over the drop on to the slide. Place the slide on the stage of the microscope with the cover-glass up, and center over the opening in the diaphragm. Turn the nose piece so that the low power objective is in line with the tube. Adjust the mirror so that the light reflected by it passes up through the slide and into the objective. With the eye on the level of the stage of the microscope, by means of the coarse adjustment lower the tube of the microscope until the front of the objective is about one-eighth of an inch from the slide. Now look through the ocular and gradually raise the tube by means of the coarse adjustment until the object comes into view. Further adjustment of the mirror may be necessary to get the best illumination.

QUESTION: How far is the front of the objective from the upper surface of the cover-glass when the object is in focus with the low power?

Move the microscopic slide about on the stage of the microscope, at the same time looking through the ocular until you find two cotton fibres crossing. Carefully observe them where they cross under the low power, changing the focus by moving the tube up and down with the coarse adjustment.

QUESTION: Can both fibres be seen at the same time where they cross?

The image seen through a microscope lacks depth and is largely confined to two dimensions.

Draw two fibres crossing. Indicate the relative positions of the fibres by making the upper one darker.

B. Focus exactly on one of the fibres and then without changing the adjustment, carefully turn the nose piece until the high power objective comes into the optical axis. The object should be approximately in focus but will require some final adjustment with the fine adjustment.

With the high power, study a part of the fibre. By focusing up and down decide whether the fibre is flat or round.

Draw a part of a fibre.

Make a diagram of what a fibre would look like in transverse section.

C. Shake the reagent bottle labeled " gum arabic " (see Appendix) until numerous air bubbles are entrapped in the solution. Place a drop on a clean slide. Add a cover-glass. Find a tiny bubble of air under the low power and study with the high power. Note the appearance of the center and periphery and any changes which occur on focusing up and down.

QUESTION: Is the dark solid appearance real or due to reflection from the surface of the bubble?

Draw an air bubble, 10 mm. in diameter.

Learn to identify air bubbles.

On another slide, place a drop of oil emulsion (see Appendix) and add a cover-glass. Study a very tiny spherical drop of oil under the high power, compare with an air bubble and learn to distinguish them. If time permits, make diagrams showing the differences and make *records*

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which will permit you to distinguish between drops of oil and bubbles of air in microscopic preparations.

D. Examine the prepared slide labeled " word " with the naked eye. This slide differs from a temporary mount in that the water has been replaced by Canada balsam. The balsam does not evaporate as water does, and it also hardens in time, so that the preparation may be kept for years. The object is a piece of paper with a word printed on it. Place the slide on the microscope so that the word may be read right side up when you look at it from the back of the microscope. Examine under the low and high powers.

QUESTION: Besides magnification what does the microscope do to the image of the object?

Under the low power move the slide to the right, to the left, up, and down.

QUESTION: How does the image move?

Draw one letter, natural size, as seen with the naked eye, and make an *outline* drawing of the same letter as seen magnified under the low power. Mark on the drawing the actual top, bottom, right, and left sides of the letter.

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III. UNITS OF PLANT LIFE

1. Cells from the Leaf of Elodea

Elodea is a water plant which grows abundantly in ponds. From the tip of a branch pick, with forceps, one of the leaves, preferably one from the bud at the end of the branch. Place in a drop of water on a microscopic slide. Flatten out the leaf and cover with a cover-glass. Examine with the low power. Choose a convenient region and study individual cells. Identify the *Cell wall* surrounding each cell.

Question: Why are the cell walls visible under the microscope only at the side of each cell and not at the top and bottom?

Small green bodies called *chloroplasts* give the green color to the leaf as a whole.

Question: How are the chloroplasts arranged in the cells?

Question: Are the chloroplasts stationary?

Question: If not, follow one and describe its movements.

The colorless substance immediately surrounding the chloroplasts is the *cytoplasm.*

Question: Is the cytoplasm in motion?

The area in the center of the cell surrounded by cytoplasm is the *vacuole.* The *nucleus* appears as a relatively large clear body in the cytoplasm usually seen bulging into the vacuole.

Draw one cell, making its width about 25 cm. (about one inch). Label all structures seen and indicate by arrows the movement of any of the bodies seen in motion.

2. Protococcus

A. Naked-Eye Examination. Observe the material provided and note the green powder on the surface of the bark.

Question: Where does Protococcus grow?

Question: Can you distinguish the separate plants with the naked eye?

B. Microscopical Examination. With a needle scrape off a little of the green powder. Mount it on a slide in water and cover with a cover-glass. Examine first with the low power and then with the high power.

Question: Is this plant composed of one or more cells?

Question: Give reasons based on the examination of the preparation.

Choose a cell to study in detail. Observe the *cell wall, chloroplast, nucleus.*

Draw the cell 35 mm. (one and one-half inches) in diameter, indicating the following structures: cell wall, chloroplast, nucleus.

Question: How many chloroplasts are there in each cell?

Question: Do you find any evidence of growth?

Draw several stages showing growth and cell division.

3. SPIROGYRA

A. Naked-Eye Features. With a needle pick up one or two of the fine green threads in the watch glass. Each of these is a Spirogyra filament.

QUESTION: How thick do the filaments appear to be?

Take a few filaments between the finger and thumb and note the silky feeling.

B. Low Power Microscopic Examination. Mount two or three filaments in a drop of water under a cover-glass, being careful not to have too much water and not to get it on the upper surface of the cover-glass. Examine under the low power.

QUESTION: Are the filaments of uniform diameter?

QUESTION: Do the filaments branch?

QUESTION: Of what is each filament composed?

Draw a section of a filament, making the width of the filament 10 mm. (about one-third of an inch), indicating *cell walls* and *protoplasm.*

C. High Power Microscopic Examination.

a. Structure of a Single Cell. Examine a single cell under the high power. Identify the *cell wall.*

Question: Is it transparent?

Question: Is it rigid?

Question: Can you recognize an inner and an outer boundary?

Question: What is the thickness of the cell wall relative to the cell?

The *cell wall* is composed of cellulose. By carefully focusing up and down determine that the cell is cylindrical in shape.

Question: How would the cell appear in cross-section?

Observe the end wall which separates the cell from its neighbors.

Question: Do you find any evidence that it is double?

In Spirogyra the chlorophyll is contained in one or more spiral *chloroplasts.*

Question: How many chloroplasts are there in one cell?

Question: Are the chloroplasts continuous from cell to cell?

The color of the chloroplast is due to chlorophyll.

Question: What is its color as seen under the microscope?

Identify the pyrenoids within the chloroplast.

Question: Can you see any starch grains?

b. Cytoplasm. The cytoplasm surrounds a large central *vacuole* and contains the chloroplast. By careful focusing find strands of cytoplasm which can be seen passing through the vacuole.

c. Nucleus. The nucleus is usually found near the center of the cell, surrounded by cytoplasm, which is connected with the fine strands referred to above.

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Draw a single cell 75 mm. (three inches) long showing the following structures: *Cell wall, Chloroplasts, Pyrenoids, Starch grains, Nucleus, Vacuole, Strands of protoplasm.*

Place a drop of iodine solution on the slide at the edge of a cover-glass and by means of a piece of filter paper applied to the opposite edge draw the iodine solution under the cover-glass.

QUESTION: What is the effect of the iodine solution?

QUESTION: What structures are stained?

d. Growth.

QUESTION: Are the cells of the same filament of the same length?

QUESTION: Do you find any evidence of cell division?

Under the low power try to find a dividing cell.

Draw to scale cells before and after cell division and, if observed, during cell division. Make the longest cells 25 mm. long.

D. Study of a Stained Preparation. Examine the prepared slide of Spirogyra. In this the Spirogyra cells have been killed, stained with certain dyes, and mounted in Canada balsam. Examine first under the low power and then under the high power.

Question: What structures have been stained by the dye?

Identify in this preparation the various structures already observed in the fresh preparation.

Question: What is the color of the chloroplast in this preparation?

Study the *nucleus.* The darkly staining granules are chromatin.

Question: What is their arrangement?

Draw the nucleus, 20 mm. in diameter, showing its structure and labeling *nucleolus* and *chromatin.*

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E. Sexual Reproduction. This may be present in the fresh preparation already studied. To obtain a complete series of stages it will probably be necessary to use a prepared slide. Examine the prepared slide showing various stages of conjugation. In some filaments observe that the conjugation tubes are just beginning to form and that the cell contents are only slightly contracted. In other filaments observe the fusion of the conjugation tubes and the contraction of the cell contents to form gametes. In a later stage the passage of one gamete (male) through the conjugation tube may be seen. In other filaments, thick walled, darkly stained zygotes which result from the fusion of gametes may be observed. Look for the empty filaments from which the male gametes have migrated.

Draw a series of stages illustrating sexual reproduction in Spirogyra.

4. YEAST

A. General Examination of a Culture. Observe a culture of yeast in molasses (see Appendix).

QUESTION: From your reading in the text, what gas do you consider to be inside the bubbles?

Test the odor.

QUESTION: What does it remind you of?

B. Microscopic Examination. Take a small drop, preferably from the bottom of the vessel, and mount on a microscopic slide under a cover-glass. Examine first under the low power and then under the high power. Note the numerous small oval bodies.

QUESTION: What is the color of the yeast cell?

Choose a part of the slide in which there are not too many cells and observe carefully. Identify the *cell wall* and *vacuole.* The nucleus is not visible in a fresh preparation.

QUESTION: How do the yeast cells reproduce?

The process is called budding.

QUESTION: Are all the cells of the same size?

QUESTION: Do the cells form colonies?

Draw in outline a group of yeast cells showing budding.

QUESTION: What evidences have you found that the bodies observed in the yeast culture are living organisms?

Name------------------------------------ *Section*------------------------- *Date*--------

IV. UNITS OF ANIMAL LIFE

1. Amoeba

A. Search for amoebae *under the low power* on a slide containing a drop of water from an amoeba culture. Adjust the diaphragm so as to have only enough light to see the smallest objects clearly. Considerable difficulty may be encountered in finding an amoeba. The movement of amoeba is exceedingly slow and may not at first be recognized. However, when once an amoeba is seen nothing else can be mistaken for it.

Movement of Amoeba. Having found an amoeba suitable for detailed observation watch it under the lower power.

Draw a series of six or more outlines at suitable intervals of time showing the changes in shape. The drawings should be on such a scale that the longest diameter of the amoeba is approximately 25 mm.

The processes which the amoeba sends out are called *pseudopodia.* Identify the outer clear *ectoplasm* and the inner granular *endoplasm.*

Question: When first formed does a pseudopodium contain both ectoplasm and endoplasm?

B. Detailed Study of Living Amoeba. Look for the *contractile vacuole.* This will be recognized by its periodic contractions.

Question: Does the contractile vacuole always appear again in the same place after contracting?

Identify the *nucleus.* This may be confused with the contractile vacuole. Its contents are, however, granular, more dense, and its shape is usually somewhat ovoid, while that of the contractile vacuole is spherical. Be on the lookout for an amoeba feeding. If one is found observe the process of formation of the food *vacuoles.* Also observe food vacuoles in the amoeba.

Question: What do these vacuoles contain?

Question: Can you recognize organisms in any of them?

Draw an amoeba, making your drawing approximately 100 mm. across. Show all the structures observed in outline. At one end of the amoeba show the difference in structure between the ectoplasm and endoplasm by stippling. Indicate and label *Plasma membrane, Ectoplasm, Endoplasm, Pseudopodium, Food vacuoles, Contractile vacuoles, Nucleus.*

C. Study of a Prepared Slide. Examine the prepared slide of Amoeba, stained and mounted in Canada balsam. Observe first with the low power and then with the high power.

QUESTION: What structures are stained?

QUESTION: What color are they?

Identify in this stained preparation the structures seen in the fresh preparation. Study particularly the nucleus.

QUESTION: How is it stained?

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QUESTION: Can you identify the *chromatin?*

2. EUGLENA

A. Observe a culture of Euglena in a culture jar. The masses of Euglena may be recognized by their green color.

QUESTION: Do they show any orientation to light or to the surface of the water?

Place a drop of water containing some of the green bodies on a slide and cover with a coverglass. Observe first with the low power. Euglena may occur in two forms; spherical non-motile *cysts*, and elongated actively *motile forms.* If possible choose one of the latter for detailed observation under the high power. Movement is of two kinds, by means of the flagellum and by means of contractions of the body. The former is much the more rapid. Careful adjustment of the light and quick observation are necessary to follow the whip-like movement of the *flagellum*, which is attached to the blunt anterior end of the Euglena.

QUESTION: Do the movements of the flagellum pull or push the Euglena along?

The contractions of the body (*euglenoid movement*) are characteristic.

QUESTION: Is the shape of the Euglena relatively fixed?

QUESTION: Are pseudopodia formed?

QUESTION: What evidence is there of a *pellicle?*

In a specimen which is not in too active movement identify at the anterior end the small *mouth* leading into the *gullet.* Near the gullet is the *eye-spot* or *stigma*, and the *reservoir* which appears as a round clear spot. Around the reservoir contractile vacuoles may be observed. Chloroplasts are distributed in the cytoplasm. The nucleus is often not visible in the living organism; it is a fairly large ovoid body located near the center.

Draw a Euglena about 100 mm. long indicating and labeling *Pellicle, Mouth, Gullet, Reservoir, Contractile vacuole, Eye-spot, Chloroplasts.*

B. If possible observe an encysted Euglena. Identify the *cyst wall.* Try to determine its thickness. Within the cyst note the chloroplasts. The stigma or eye-spot is often quite conspicuous in cysts.

Question: How many individuals does the cyst contain?

Draw a cyst 50 mm. in diameter, indicating and labeling *Cyst wall, Individuals, Eye-spots.*

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3. PARAMECIUM

A. Naked-Eye Observations. Examine a culture of Paramecium. An individual Paramecium is just large enough to be visible to the naked eye as a small white dot.

QUESTION: Do the animals tend to collect in a particular region in the culture?

QUESTION: What is the relation of this region to the light and air supply?

B. Microscopic Examination. Mount a drop from a culture of Paramecium on a slide under a cover-glass and observe with the low power. Numerous other small organisms usually occur in cultures of paramecium. Paramecium may be recognized by its relatively large size, shape, and movement. It rotates as it moves through the water. On encountering an obstacle it reverses its motion, pauses, swings its anterior end around and starts off in another direction.

QUESTION: How can the *anterior* and *posterior* ends be distinguished?

Try to follow the locomotion of an individual. Note the *oral groove.* The surface on which this occurs is called the *ventral surface.* The opposite surface is called the *dorsal surface.*

C. Ciliary Movement and Formation of Food Vacuoles. Cut a square of lens paper slightly smaller than a cover-glass, place on the center of a clean slide, place a drop of paramecium culture on a clean slide, dust over it a small amount of powdered gum arabic, add a drop of carmine suspension (see Appendix) and cover with a cover-glass. Under the low power look for an individual which is quiet and study it under the high power, noting particularly the beating of the cilia and the currents of water going down the oral groove.

D. Details of Structure. Study the details of structure under the high power. By focusing on the edge of an individual watch the movement of the *cilia.*

QUESTION: Do the cilia move synchronously?

QUESTION: Are the cilia of equal length all over the body?

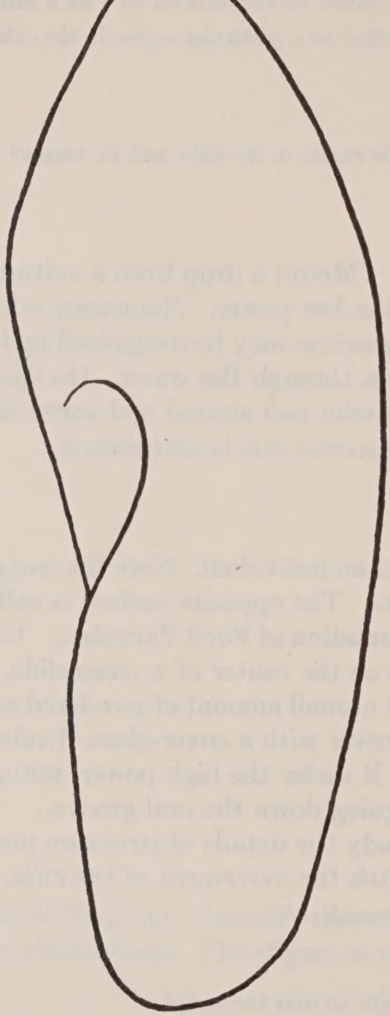
QUESTION: To what is the more or less fixed shape of the cells due?

Draw in the cilia on the prepared outline and label posterior and anterior.

Within the *ectoplasm* is the granular *endoplasm.* In the oral groove look for a clear area, the *mouth,* leading into a funnel-shaped cavity, the *gullet,* containing an *undulating membrane.* Watch the movement of the undulating membrane. Identify the food vacuoles.

QUESTION: Can you recognize any of the contents of the food vacuoles?

Draw in on the printed outline and label the following: *Ectoplasm, Endoplasm, Mouth, Gullet, Undulating membrane, Food vacuole, Anterior, Posterior, Oral groove.*



II
PARAMECIUM

At either end is a *contractile vacuole.* Watch for its contraction, which may have been slowed down by the gum arabic. Identify the *radial canals* leading to the vacuole.

Draw in on the printed outline the *contractile vacuoles.*

Under the pellicle in the ectoplasm are numerous *trichocysts.* Place a drop of Methyl Green solution (see Appendix) on the slide at the edge of the cover-glass and by means of a piece of filter paper applied to the opposite edge suck the Methyl Green under the cover-glass.

QUESTION: Which structures are stained by the Methyl Green?

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E. Examine a *prepared slide* of Paramecium in which the animals have been killed, stained, and mounted in Canada balsam. Identify the *macronucleus* near the center, and, if possible, on one side of it, the small *micronucleus.* Add the macronucleus and micronucleus to your drawing. Search the slide for individuals in *division.* Find a stage in which the nuclei are in the process of division.

Draw a paramecium in division on such a scale that the individual is 50 mm. long.

4. Cells of the Frog's Epidermis

A. Naked-Eye Observation. Examine some of the cast-off epidermis of the frog.

QUESTION: What is its general appearance?

QUESTION: How thick does it appear?

B. Microscopical Examination. Mount in water on a slide under a cover-glass some fresh cast-off epidermis or epidermis which has been preserved in formalin, or use a prepared slide.

QUESTION: What is the shape of the cells?

QUESTION: Does each cell contain a nucleus?

Draw **a group of cells making the diameter of a cell about 20 mm.**

5. Blood Cells of the Frog

A. Study of Fresh Preparation. Place a very small drop of frog's blood on a slide and add a drop of 0.8% sodium chloride (NaCl) solution.

QUESTION: Why not add tap water?

Cover with a cover-glass. Examine with the low power. Identify the *red blood corpuscles* or *erythrocytes.* Examine some of these under the high power.

QUESTION: What is their shape?

In determining this look for and compare corpuscles seen on edge with those which lie flat.

QUESTION: Where is the haemoglobin?

By carefully adjusting the diaphragm and focusing, identify the nucleus.

Draw an erythrocyte, making its diameter about 20 mm.

Look for small, irregular, roundish, white bodies, the *leucocytes,* about half the diameter of the red corpuscles. Examine one of these.

QUESTION: Do they resemble an amoeba?

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Watch for *amoeboid movement.*

B. Study of Stained Preparation. Obtain a prepared slide of frog's blood stained and mounted in Canada balsam. Certain structures such as the nuclei can now be more clearly seen. If you have been unable to see them in the fresh preparation add them to your drawing now.

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V. PROTOPLASM

1. DIFFUSION AND OSMOSIS

A. Diffusion. Observe an experiment in which a crystal of copper sulphate has been placed in a beaker of water, at the beginning of the laboratory period and again toward the end of the period.

QUESTION: What changes have occurred?

B. Osmotic Pressure.

a. Observe the demonstration of osmotic pressure.

Draw a diagram of the apparatus and make records of the height of the column of liquid at half-hour intervals during the laboratory period.

b. Carefully remove from the blunt end of a hen's egg a circular portion of the shell about 30 mm. in diameter. Support the egg in a vessel of water with the pointed end down so that the level of the water comes near but not quite up to the broken portion of the shell.

QUESTION: What changes occur?

Draw a diagram and indicate the contour of the membrane at the beginning and end of the laboratory period.

C. Osmotic Growth in Solutions. Fill a test-tube or vial two-thirds full of a 3% solution of copper sulphate ($CuSO_4$). Into this place a crystal about the size of a rice grain, of potassium ferrocyanide, $K_4Fe(CN)_6$. Place the test-tube or vial where it can be observed without being disturbed.

Draw diagrams at intervals showing the extent of growth.

D. Plasmolysis. Carefully mount a few filaments of Spirogyra or an Elodea leaf in water on a slide under a cover-glass.

Draw **a few cells and the contained protoplasts.**

Place a drop of 5% salt solution at one edge of the cover-glass and by means of a piece of filter paper applied to the opposite edge suck the salt solution under the cover-glass. Observe the cells, those previously drawn, if possible.

Draw **a few cells and the contained protoplasts showing the effect of the salt solution.**

Replace the salt solution by water.

Question: Do the protoplasts return to their normal condition?

2. The Colloidal State

A. Suspensions.

a. To a solution of barium chloride ($BaCl_2$) add some dilute sulphuric acid (H_2SO_4). The fine white precipitate is barium sulphate ($BaSO_4$). Note how gradually it settles. After the precipitate has settled somewhat place a few drops in a watch glass and examine under the low power of the microscope.

Question: Estimate the size of the particles.

Label the test-tube, set it aside and observe later whether the particles settle out from the water.

Question: State to what extent the particles have settled out.

b. "Place one drop of olive oil in a test-tube and half fill the tube with alcohol. Shake well and pour into a beaker of water. A fine white emulsion of oil in water will be formed from which the oil will not separate. By this method the oil is obtained in such small drops that stability is ensured." [1] Place a few drops of the emulsion in a watch glass and examine under the low power of the microscope.

Question: What is their size and shape?

Set the beaker aside and observe whether the oil settles out.

Question: Did the oil settle out at the end of the period?

B. Brownian Movement. Observe the demonstration of Brownian movement. For this a dark field condenser is used under the stage of the microscope and a strong source of light. By this means the particles in the liquid under the microscope are illuminated from the side and appear against a dark background. Note the movement of the particles and try to follow a particular particle.

Question: Which moves the faster, a smaller or a larger particle?

C. Gelation. Place a small quantity, enough to make about a 2% solution, of the powdered gelatin in a test-tube half full of water. Warm until the gelatin is "dissolved," forming a colloid solution, being careful not to apply too much heat. Allow to cool.

Question: What is formed?

Heat again.

Question: What change do you observe?

Question: Is the process of gelation of gelatin reversible?

D. Coagulation. Add some fresh egg albumin to water in a test-tube. Warm.

Question: What occurs?

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[1] Quoted from Onslow, *Plant Biochemistry*, p. 13.

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Allow to cool.

Question: Is coagulation reversible?

3. Tests for Organic Substances

A. Test for Starch.

a. Place a small quantity (about as much as can be taken up on 10 mm. of the blade of your scalpel) in a test-tube one-quarter full of water and shake well.

Question: Is the starch soluble?

Bring the mixture to a boil over the alcohol lamp.

Question: What changes do you observe?

Set the test-tube aside to cool.

b. Add three or four drops of Lugol's iodine solution (see Appendix) to a test-tube one-quarter full of clear water. Record the color. Add one or two drops of the iodine solution to the cool boiled starch mixture made as above. Shake and record the color. Dilute by pouring one-half of the starch, water, and iodine mixture (i.e., 1/8 test-tube full) into 1/2 test-tube full of water.

Question: Describe how a test for starch may be made.

c. Starch in Plants. Boil a piece of potato as an example of a stem in water in a test-tube and test for starch as above.

Question: What do you observe?

Do the same for the piece of the root and seed provided.

Question: Compare the result with that obtained above.

B. Test for Fats.

a. Place a few drops of olive oil in a test-tube, add water and shake.

Question: Does the olive oil dissolve?

Do the same adding instead of water five or six cubic centimeters of carbon tetrachloride (CCl_4).

QUESTION: Is olive oil soluble in carbon tetrachloride?

Evaporate the carbon tetrachloride over the alcohol lamp.

QUESTION: What remains?

b. The above procedure provides a test for *fats.* Grind up the kernel of a walnut, in carbon tetrachloride. Filter through filter paper. Evaporate.

QUESTION: What remains?

QUESTION: Do walnuts contain fat?

C. Tests for Proteins. Crush the kernels of two or three walnuts in 10 cc. of a 0.5% solution of sodium hydroxide (NaOH) and filter into a test-tube.

a. Biuret Reaction. Pour about 5 cc. of the Gies-Biuret solution (which consists of 40% NaOH to which $CaSO_4$ has been added drop by drop until the color is distinctly blue and *should be handled carefully* on account of its caustic properties) into a test-tube. By tilting the test-tube gently flow about half of the solution obtained from the walnut over the Gies-Biuret solution without mixing. If protein is present a pink to violet ring will be seen where the two solutions meet.

QUESTION: Does the walnut contain protein?

Draw a diagram showing the result of a positive xanthroproteic reaction.

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b. Xanthroproteic Reaction. To the other half of the solution obtained from the walnut kernels add about one-third of its volume of strong nitric acid (HNO_3). (Handle the nitric acid carefully to avoid burns.) A white precipitate is formed. On boiling, the precipitate turns yellow, and may partly dissolve to give a yellow solution. Cool under the tap and add strong ammonia till the reaction is alkaline. The yellow color becomes orange.[1]

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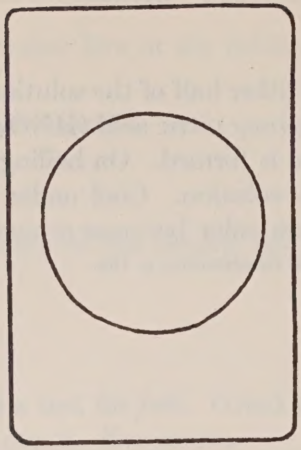
[1] **For explanation of these tests see Onslow, *Plant Biochemistry*, p. 136.**



Resting stage

Early prophase

Late prophase

Metaphase

Anaphase

Early telophase

Late telophase

III

CELL DIVISION

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VI. CELL DIVISION

Study cell division in the prepared longitudinal section of the root tip of the onion. The stages listed below will probably not be found in the order given. It is most convenient when a good example of any particular stage is found to draw it at that time in its proper place on the page. Apart from the resting stage approximately six stages in the process of cell division will be recognized. These are divided among four phases, prophase, metaphase, anaphase, and telophase, there being an early and a late prophase, and an early and a late telophase.

1. Resting Stage

The resting stage is usually the most numerous in preparations since the cell remains longest in this stage. The *nuclear membrane* is intact. The chromatin is in the form of scattered granules and there are one to three deeply stained *nucleoli*.

Draw a resting stage in the space provided.

2. Early Prophase

In the early prophase the nuclear membrane is still intact and the nucleolus is present. The chromatin is condensed in certain parts of the nucleus.

Draw an early prophase in the space provided.

3. Late Prophase

In the late prophase the nuclear membrane has begun to break down, the nucleolus has disappeared and the chromatin spireme has broken up into separate *chromosomes*.

Draw a late prophase in the space provided.

4. Metaphase

In the metaphase the nuclear membrane has completely disappeared and the chromosomes, which in the meantime have each split longitudinally into two, are arranged with the two halves on opposite sides of an equatorial plate which is in a plane at right angles to the longitudinal axis of the cell.

Draw a metaphase on the same scale as the previous stage, in the space provided.

5. Anaphase

In the anaphase the chromosomes are seen moving towards the opposite ends of the cell where the spindle fibres meet.

Draw an anaphase on the same scale as the previous stages, in the space provided.

6. Early Telophase

In an early telophase the chromosomes have just arrived at the ends of the cell where they are clumped together.

Draw an early telophase on the same scale as the previous stages, in the space provided.

7. Late Telophase

In a late telophase the chromatin is returning to the granular form in which it appeared in the resting nucleus and a cell wall is forming across the cell, dividing it into two new cells.

Draw a late telophase on the same scale as the other stages, in the space provided.

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VII. THALLOPHYTES

1. Algae

A. Oedogonium (a Green Alga).

a. If fresh material is available observe the living plant in a culture and under the microscope. If such material is not available the exercise, with the exception of the motile stages, may be done on a prepared slide.

Question: How is the plant attached?

Draw a filament.

b. Asexual Reproduction. Under the microscope look for filaments showing spore formation and for *zoospores* in the preparation.

Draw a zoospore.

c. Sexual Reproduction. Look for filaments containing *antheridia* or *oogonia.* The antheridia are small cells and produce one or two *sperms.* The oogonia are large cells and produce a single *egg.*

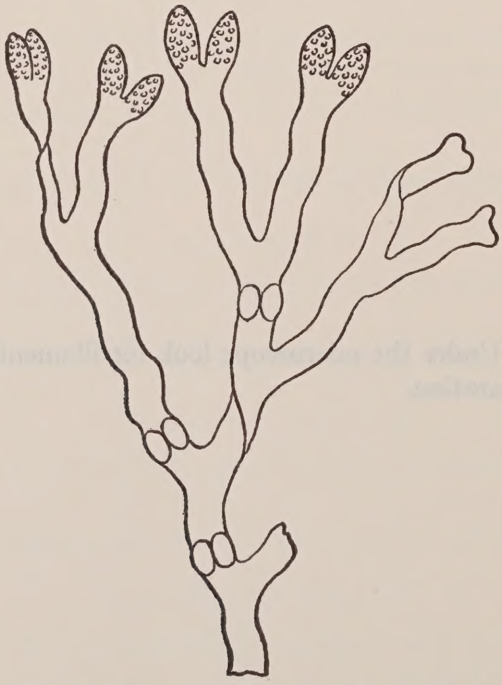
Draw portions of filaments showing antheridia and oogonia.

B. Fucus (a Brown Alga).

a. The Plant as a Whole. Fucus grows on the sea coast on rocks between tide levels. Observe the forked ribbon-like *thallus* (this type of branching is called dichotomy), the *holdfast* (often torn off in collecting) which anchors the plant to the rocks, and the *gas bladders* containing carbon dioxide, which help to keep the plant afloat.

Two kinds of branches can be distinguished. Those which have flat ends are *vegetative branches.* Those with swollen ends contain the reproductive organs and are called *fruiting branches.*

Label the prepared drawing of a plant of Fucus.



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Fucus

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b. Growing Point. Examine the tip of one of the vegetative branches under the low power of the microscope. Note the notch at the end. With a sharp scalpel cut across the branch at its extreme tip and stand the piece on end with the notch uppermost on a slide. Note the pit in which the growing point is located.

c. Sexual Reproduction. The reproductive organs lie in cavities called *conceptacles* which open to the surface of the thallus by *ostioles.* Cut a swollen tip of a plant and observe the minute round conceptacles.

d. On the prepared slide containing a section of a male fucus conceptacle note the *conceptacle;* the opening to the surface, called the *ostiole*, and the straight hairs or *paraphyses*, arising from the wall of the conceptacle. Amongst the paraphyses will be found branching hairs which bear sac-like organs, the *antheridia.* In these are found numerous *sperm.*

Draw an outline of a section of a male conceptacle showing a few antheridia.

e. After the male Fucus plants have been out of water for some time, the sperm ooze out of the conceptacles in orange masses. Add a small amount of the sperm to a slide, iodine solution and a cover-glass. Examine under the microscope. Note the cilia on the sperm.

Draw one sperm 30 mm. in length.

f. On the prepared slide containing a section of a female conceptacle note the *conceptacle, ostiole, paraphyses,* and *oogonia* (sac-like organs borne on short stalks) containing the *eggs.*

Draw a female conceptacle in outline 60 mm. in diameter, labeling all the parts.

g. In fresh female Fucus plants which have been out of the water for some time the eggs ooze out in greenish brown masses. Gather some of these masses on a slide and identify the individual cells with the naked eye; then add iodine solution and a cover-glass. Examine under the microscope.

Draw an egg 30 mm. in diameter.

h. Demonstration of Fertilization. Clean four slides and lay them on the desk. The instructor will add a small drop containing unfertilized eggs to each and then a drop containing sperm. Add cover-glasses and examine *immediately* as fertilization may take place in a few seconds. The sperms will collect about the eggs and if abundant enough will set the egg in rapid rotation. Watch for the formation of a *fertilization* membrane about the egg. This will appear suddenly as a semitransparent film around the egg. It is formed after a sperm has entered the egg and its function appears to be to exclude other sperm.

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Draw a fertilized egg (zygote) showing the fertilization membrane and a few sperm collected around it.

Note. Do not clean slides on which fertilization has taken place. These should be kept and allowed to develop.

i. Examine slides in which fertilization has already taken place, for signs of cell division (segmentation).

Draw one zygote showing segmentation if found. Make the drawing 30 mm. in diameter.

2. FUNGI

A. Bacteria (a Group of the Fungi).

a. Place a drop of water from a culture of bacteria on a slide. Add a cover-glass and examine under the low and high powers. Numerous small objects will be seen moving in the field. These are bacteria. Bacteria are divided into three groups according to their shape. The rod-like forms are called *bacilli* or bacillus bacteria; the spherical forms, *cocci* or coccus bacteria; and the spiral or corkscrew-like form *spirilla.* Find the three forms, note their movements, if any. Notice if the bacteria form groups or chains.

Draw one or more individuals of each kind of bacteria, making each 15 mm. in length.

b. Mount some of the scum from the top of the culture on a slide, add a cover-glass and examine under the high power. At times certain bacteria secrete a gelatinous covering around them and form spores. The spores in their gelatinous matrix rise to the surface of the water, and stick together. Find the spherical spores with thick walls and gelatinous capsule.

Draw a spore 10 mm. in diameter.

c. With a clean needle scrape around the base of your teeth, mount the scrapings in water on a slide, add a cover-glass and examine under the high power.

Draw different forms of bacteria found.

d. If available examine one or more plate cultures of bacteria on agar or gelatin in Petri dishes. Note differences in size, color, texture, and shape in the cultures.

Draw a few cultures.

B. The Bread Mold—Rhizopus nigricans (a Saprophytic Fungus).

a. Naked-Eye Observations. On a piece of bread notice the gray fuzz which may be black on the surface. Examine it with the hand lens. The gray fuzz is due to innumerable fine filaments or *hyphae* which grow over and into the bread. That the hyphae are able to grow into the bread is due to their giving off an enzyme which digests it as they grow into its substance. On the surface observe the larger hyphae or *stolons* growing just above the surface for short distances and then coming into contact with the bread, at which points a number of branches are produced and penetrate the bread. *Erect branches* may be seen at these points. They terminate in gray (immature) or black (mature) swollen ends. These erect branches are the sporangiophores and their swollen ends are *sporangia.* When bread mold is grown in a stender dish with the cover

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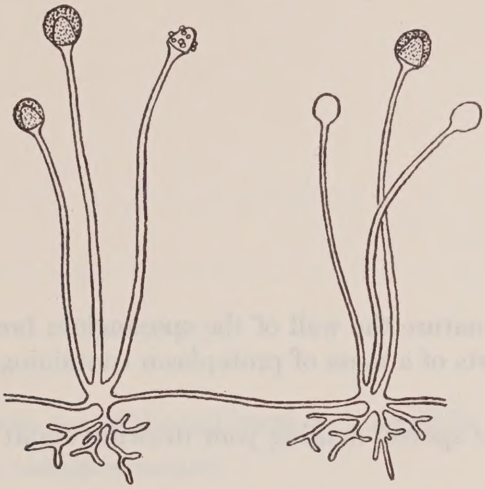
on, hyphae will grow over the under side of the cover. Observe the hyphae on the under side of the cover.

Label on the printed outline the structures identified.



V

Rhizopus nigricans, the Bread Mold

b. Hyphae. Mount some of the hyphae preferably from the glass cover on a slide in a 10% solution of glycerine, add a cover-glass and examine under the microscope. Notice that the filaments are bounded by a *cell wall* and *plasma membrane* (latter not visible as a separate structure), and that the protoplasm is not divided into cells by cross walls but consists of a continuous mass containing many *nuclei.* Such an arrangement is called a *coenocyte.* If the nuclei are not visible run a little Lugol's solution (see Appendix) under the cover-glass to stain them.

Draw a few hyphae, 10 mm. in diameter, indicating all the structures you have observed, and adding arrows to show the direction of streaming.

c. Asexual Reproduction. If your preparation does not show a *sporangium,* make a new preparation and find the following under the microscope: a *sporangiophore* or erect hyphae, bearing on its outer end a swollen *sporangium.*

The sporangium is made up of three parts, the outer wall, a central portion called the columella, and a portion between these in which the spores are developed. In young sporangia this latter part will be found to consist of a dense mass of protoplasm. In older sporangia, *spores* will have formed and will be colored black from the color of the *spore walls.* In still older sporangia chiefly columellae from ruptured sporangia will be seen.

Draw one or more sporangia in different stages of development, making the sporangia at least 15 mm. in diameter.

After the spores become mature the wall of the sporangium breaks down and the spores are liberated. Each spore consists of a mass of protoplasm containing many nuclei and covered by a resistant wall.

Draw one or more mature spores, making your drawing about 10 mm. in diameter.

d. Sexual Reproduction. Under certain conditions sexual reproduction occurs. Some of the hyphae develop club-shaped lateral branches which come in contact at their tips. The protoplasm at the end of each of these becomes more dense and is cut off from the rest of the hypha by a cell wall. Later the cell walls separating the tips of the branches which have come in contact dissolve and the two protoplasmic masses fuse. A new cell wall forms around the fused mass which becomes a *zygospore* which in this case contains a number of nuclei.

Draw one or more stages in the formation of a zygospore, making your drawings about 15 mm. in diameter.

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C. The Wheat Rust—Puccinia graminis (a Parasitic Fungus).

a. Red Rust on Wheat. Examine the leaf or stem of a wheat plant with red rust (uredospores). Note the position of the red spots (sori).

Draw an infected area.

Scrape some uredospores from one of the red spots and mount in water under a cover-glass.

Question: How many cells does a uredospore contain?

Draw one or two uredospores.

b. Black Rust on Wheat. Examine the leaf or stem of a wheat plant with black rust (teleutospores). Note the position of the black areas.

Draw an infected area.

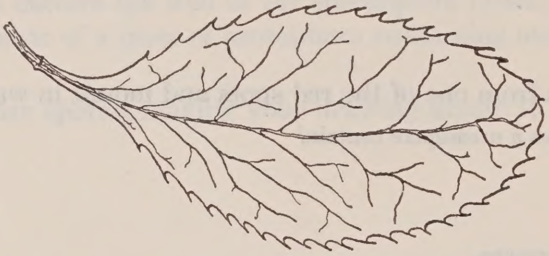
Scrape some teleutospores from an infected area and mount in water under a cover-glass.

Question: How many cells does a teleutospore contain?

Draw a teleutospore.

c. The Rust on the Barberry. Examine the upper side of an infected barberry leaf for *spermogonia* and the under side for *aecidia.*

Draw in the printed outline the infected parts of the under side of the barberry leaf.



VI

Puccinia graminis in Barberry Leaf

Study a prepared section of an infected barberry leaf.

Draw an aecidium showing aecidiospores and a spermogonium.

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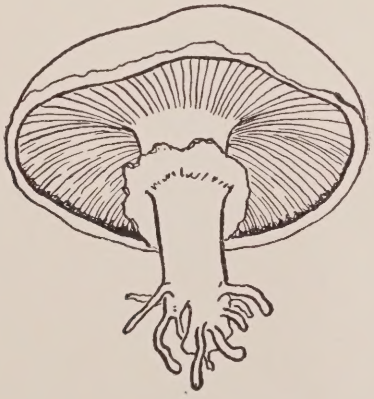
d. Life-Cycle.

Draw a diagram of the life-cycle of the wheat rust using words or simple drawings to indicate stages.

D. A Mushroom (a Saprophytic Fungus).

a. Fruiting Body. Examine various stages in the development of a "mushroom" or fruiting body.

Label on the prepared outline *Cap, Gills, Stalk, Mycelium*



VII

A Mushroom, Agaricus

b. Spores. Make a "spore print" by cutting the cap from a ripe mushroom and placing it with the gills downward on a piece of white paper.

Question: How do the spores come to be arranged as they are?

Tease out a small piece of gill on a slide in water and look for spores.

Draw a few spores.

c. Gills. Make a thin free-hand section of the cap, cutting across the gills with a razor blade and mount it in water under a cover-glass or obtain a prepared section of the gills. The surface of the gills, called the *hymenium*, contains numerous club-shaped cells called *basidia*, which bear the *spores* on short stalks called *sterigmata.*

Question: How many spores are borne by a basidium?

Draw a portion of a gill showing basidia and spores, labeling, *Gill, Hymenium, Basidium, Spores, Sterigmata.*

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3. A LICHEN

A. Study a common lichen. Note its appearance and mode of growth.

B. Make a thin section of a lichen with a razor blade and mount in water or obtain a prepared section. A lichen is composed of a fungus and an alga growing in symbiosis. Identify the algal cell and the hyphae of the fungus.

Draw a portion of the section showing *Cell of Alga*, and *Hyphae of Fungus.*

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VIII. BRYOPHYTES

1. A LIVERWORT

Examine the *thallus* of Marchantia or another common liverwort. Note the form of the thallus and its differentiation into *anterior* and *posterior* ends and into dorsal and ventral surfaces. Observe the growing point in a notch at the anterior end of each branch.

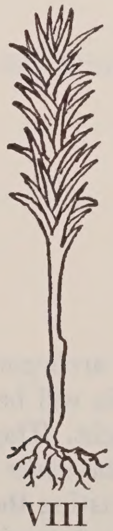
QUESTION: Compare the thallus of a liverwort with the thallus of an alga such as Fucus.

Draw the thallus 75 mm. long.

2. A MOSS

A. Examine a " moss plant " or *gametophore.* Leaves arise from the stem. Rhizoids, colorless or brownish filaments that arise near the base of the axis, may sometimes be seen.

Label the following on the prepared outline drawing of a moss gametophore: *Stem, Leaves, Rhizoids.*



VIII

A MOSS GAMETOPHORE

Examine a leaf in water under a cover-glass with the low power of the microscope.

Question: How many cells thick is it?

Question: What is the function of the leaves?

B. Place the tip of the plant marked " antheridia " on a glass slide. With dissecting needles dissect the leaves away from the tip. Cut the exposed tip off from the stem and tease out in water on the slide. Cover with a cover-glass and examine with the low power. The *antheridia* are sausage-shaped bodies, white by reflected light and opaque to transmitted light. Identify the *jacket cells* and the contained mass of *spermatozoids.* Among the antheridia are multicellular hairs called *paraphyses.*

Draw an antheridium 50 mm. long and a paraphysis to the same scale. Label *Antheridium, Jacket cells, Spermatozoids, Paraphysis.*

C. Dissect the tip of the plant marked " archegonia " in the same way as you dissected the plant marked "antheridia." The archegonia will be recognized as elongated bodies, white by reflected light and opaque to transmitted light. They are somewhat swollen near their attachment to the stem. The swollen portion is the *venter* in which the egg is contained; the slender outer portion is the neck. By properly adjusting the light, the *egg* can be seen. Multicellular hairs or *paraphyses* are present among the archegonia.

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Draw an archegonium 75 mm. long and label *Archegonium*, *Venter*, *Neck*, and *Egg*.

D. Examine a moss plant bearing a sporophyte. With forceps grasp the tip and pull gently. An inverted cup-like structure, the *calyptra*, will be removed, exposing the *capsule*. Place it in its correct position at the top of a sheet of paper. With your fingers grasp the thin portion of the sporophyte and pull gently. The sporophyte will separate from the gametophyte. Arrange the sporophyte and gametophyte in the correct relative positions. The calyptra is the upper part of the archegonium. Observe the remains of the neck and venter. In the sporophyte note the lighter *foot*, the *stalk*, and *capsule*.

QUESTION: Is the sporophyte a dependent plant?

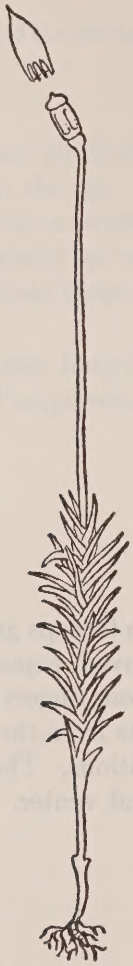
Examine in detail the capsule. Note the *lid*. With dissecting needles remove the lid of the capsule and note the teeth.

QUESTION: What is their function?

QUESTION: Where are the spores?

Label on the printed outline of a moss plant, with the sporophyte attached: *Gametophyte, Sporophyte, Stalk, Capsule, Calyptra.* Indicate position of *Foot.*

Draw the capsule at one side on a larger scale.



IX

A MOSS GAMETOPHYTE AND SPOROPHYTE

E. Crush a capsule in a drop of water on a slide and identify the *spores;* if possible find a tetrad of spores.

Draw a spore 10 mm. across or, if found, a tetrad of spores to the same scale.

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F. Study germinating spores. The branching filament that is produced on germination of the spore is called a *protonema.* On the protonema are developed buds which grow into upright leafy branches.

Draw two stages in the germination of spores on the same scale as **E** on preceding page.

Draw a diagram of the life-cycle of the moss using words or simple drawings to indicate stages.

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IX. PTERIDOPHYTES

The Fern

A. Examine a mature fern plant. Identify the leaves or *fronds*. The tips of the young leaves are coiled.

Question: Where is the growing point of the leaf?

The stem of the fern is underground and for this reason is called a *rhizome.* The *roots* arise from the stem at any point and are therefore said to be *adventitious.* On the under sides of some of the fronds small brown areas will be noticed. These are called *sori* and consist of groups of sporangia containing spores. A frond bearing sporangia is called a *sporophyll.*

Question: To what generation does the fern plant belong?

B. With a scalpel scrape the contents of a sorus onto a slide. Mount in water under a cover-glass. Study with the low power. Identify the *sporangia.*

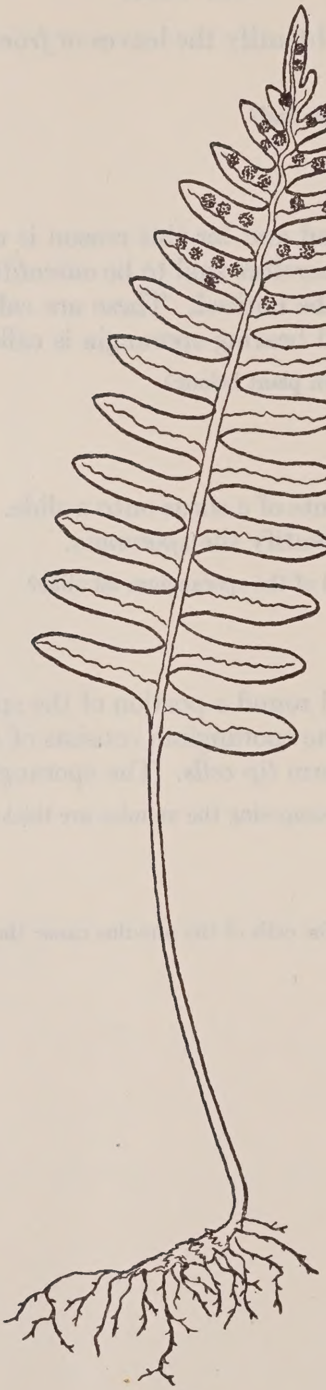
Question: Are the cells composing the wall of the sporangium all alike?

The thick walled cells which extend round a portion of the sporangium in the form of a horse shoe form the *annulus.* The rest of the sporangium consists of *sheath cells.* Two of these at one end of the annulus are modified to form *lip cells.* The sporangium opens between the lip cells.

Question: Which of the walls of the cells composing the annulus are thickest, which thinnest?

Question: How does the loss of water by the cells of the annulus cause the opening of the sporangium?

Label on the printed outline drawing the following structures: *Rhizome, Roots, Frond, Sori.*



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A Fern Plant

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Draw a sporangium 50 mm. across and some spores on the same scale, labeling: *Sporangium, Stalk, Annulus, Sheath cells, Lip cells, Spores, Tetrads.*

C. Examine some germinating spores. At first a *filament* consisting of a few cells is formed. Later a plate of cells called a *prothallus* is formed. The *rhizoids,* when they are developed can be recognized by the lack of chlorophyll in their cells.

QUESTION: Where do the rhizoids arise?

Draw two germinating spores, one, about 50 mm. long showing a filament, the other, 75 mm. long showing a young prothallus, labeling: *Filament, Rhizoids, Prothallus.*

D. Study a fresh preparation or a prepared slide of a mature prothallus showing sexual organs.

QUESTION: What is the shape of the prothallus?

QUESTION: Locate the *growing point* (anterior), the thicker *cushion*, and the *rhizoids* (posterior).

QUESTION: Are you looking at the upper (dorsal) or the lower (ventral) portion of the prothallus?

QUESTION: Does the prothallus lead an independent existence?

Draw the prothallus 100 mm. long, labeling: *Prothallus, Cushion, Growing point, Rhizoids.*

The *archegonia* develop near the growing point on the ventral portion of the prothallus at the anterior end of the cushion. Examine an archegonium and identify the *egg* and the *canal.*

Draw in several archegonia in your drawing of the prothallus.

The *antheridia* are found on the ventral side of the cushion among the cells from which the rhizoids arise. Examine one of these and identify the *sperm.*

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Draw in several antheridia in your drawing of the prothallus.

E. Study with a hand lens a prothallus from which a young *sporophyte* has grown out. In the young sporophyte identify the *primary leaf* and the *primary root.* The foot is imbedded in the prothallus.

Draw a side view of the young sporophyte attached to the prothallus (gametophyte), making the prothallus 50 mm. long.

Draw a diagram of the life-cycle of the fern using words or simple drawings to indicate stages.

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X. SPERMATOPHYTES

1. THE PINE (A GYMNOSPERM)

A. The Plant Body. Observe a pine tree.

QUESTION: What is its method of branching?

Study a branch. Note that the needles come off in clusters from short branches.

QUESTION: How many leaves in a single cluster?

Draw a single cluster of needles and the short branch which bears it.

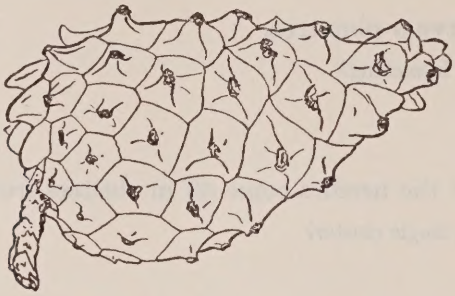
B. Carpellate Cone.

QUESTION: What relation do the carpellate cones bear to the branches of the tree?

Carefully detach the lowest scales from a carpellate cone. These scales are *megasporophylls.*

QUESTION: How are the megasporophylls arranged on the axis of the cone?

Label the megasporophylls on the printed outline of a carpellate pine cone.



XI

Pine, Carpellate Cone

Examine the upper side of a scale near where it was attached and notice the two *ovules*.
Draw the upper side of a scale showing ovules.

C. An Ovule. Study a longitudinal section of a young ovule. Note the *integuments*, *microphyle*, and *megasporangium*. The latter may already contain a *female gametophyte*.
Draw the longitudinal section labeling the structures identified.

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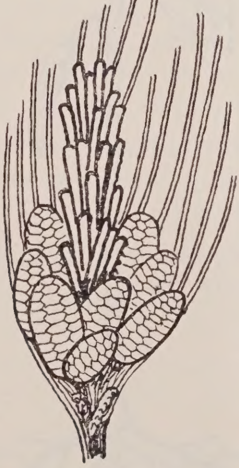
Study a longitudinal section of a nearly mature ovule and look for archegonia in the female gametophyte.

Draw a section showing an archegonium.

D. A Staminate Cone.

Question: How do the staminate cones occur on the tree?

Label the structures on the printed drawing of a staminate pine cone.



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Pine, Staminate Cone

a. Remove a number of scales beginning at the base of the cone. Examine the under sides of the scales (microsporophylls) and find the *pollen sacs* or *microsporangia*.

Draw the under side of a microsporophyll showing the pollen sacs.

b. Open one of the pollen sacs and mount some of the pollen grains (microspores) on a microscopic slide in water under a cover-glass. Study with the low power followed by the high power.

Draw a few pollen grains.

E. The Seed. Study some pine seeds which have been soaked in water to soften the seed coat. The *seed coat* is developed from the integument of the ovule. Carefully tear off the seed coat and note that most of the food material is stored in the *female gametophyte* in the center of which is the *embryo.* Separate the embryo and identify the following parts: *cotyledons, hypocotyl.*

QUESTION: List the parts of the seed and state to which generation each belongs.

Draw the embryo.

2. FLOWERING PLANTS (ANGIOSPERMS)

A. The Plant as a Whole (Sporophyte). Examine a young sunflower plant. Note its division into *root* and *shoot.* In the shoot note the division into *stem* and *leaves.* Observe the root. Can you distinguish *primary* and *secondary roots?* In a leaf note the *petiole* and *blade.*

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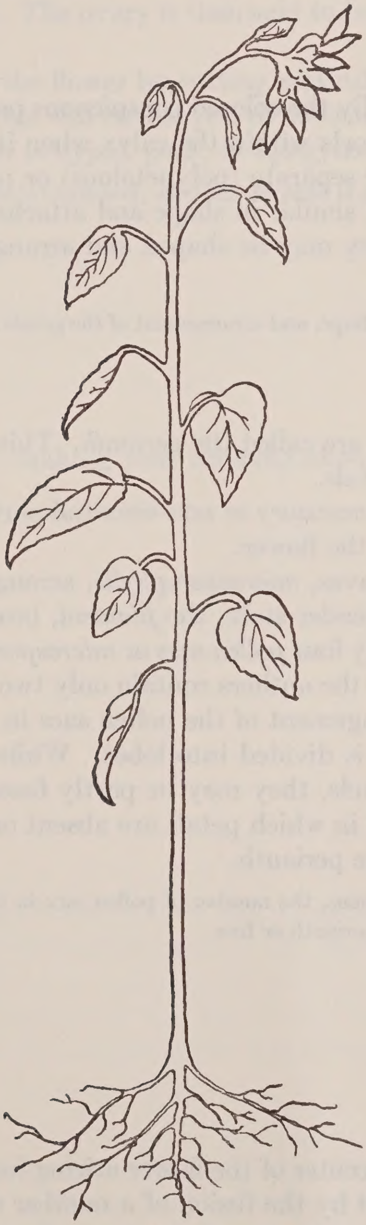
QUESTION: How are the veins arranged?

QUESTION: Do they continue into the petiole?

In the stem distinguish between *nodes* and *internodes*. ***Label*** the outline drawing of a young sunflower plant.



XIII
SUNFLOWER PLANT

B. The Flower. From the point of view of its structure and development the flower can be considered as a much shortened stem on which whorls of modified leaves are borne. This shortened flattened portion of the stem is called the *receptacle.* On the receptacle the outermost whorls of leaves correspond to those lower down on an ordinary stem, the innermost whorls to those at the tip of the stem. Examine the flower provided using when necessary the hand lens. Identify the whorls of modified leaves as follows:

a. Sepals. Usually leaf-like and green, but sometimes absent, or colored and indistinguishable from the petals. The sepals together form the *calyx,* and they may be separate or fused together to form a cup-like structure.

QUESTION: Record the presence or absence of sepals, their number, color, arrangement, and whether fused or separate.

b. Petals. The petals are usually the colored conspicuous part of the flower. They arise from the receptacle in one or more whorls within the calyx when it is present. The petals together form the *corolla* and they may be separate (polypetalous) or partly or completely fused (gamepetalous). The petals may be all similar in shape and attachment to the receptacle, when the flower is said to be *regular,* or they may be shaped and arranged so as to form a *bisymmetrical* (*zygomorphic*) flower.

QUESTION: Record the number, color, shape, and arrangement of the petals and whether they are fused or separate.

The calyx and corolla together are called the *perianth.* This is a useful term when the sepals are indistinguishable from the petals.

The calyx and corolla form the *accessory* or non-essential parts of the flower. The parts which follow form the *essential* parts of the flower.

c. Stamens. Much modified leaves, *microsporophylls,* arranged in one or more whorls within the corolla. Each consists of a slender stalk, the *filament,* bearing at its apex an enlargement, the *anther,* within which are usually four *pollen sacs* or *microsporangia,* arranged in pairs on either side of the stalk. In some flowers the anthers contain only two pollen sacs, one on either side of the stalk. The number and arrangement of the pollen sacs in the anther can usually be determined from the way in which it is divided into lobes. While the regular condition is for the stamens to arise from the receptacle, they may be partly fused with the corolla and appear to arise from the petals or in flowers in which petals are absent or the petals fused with the sepals they may appear to arise from the perianth.

QUESTION: Record the number of stamens, the number of pollen sacs in the anther and whether the filaments of the anther are adherent to the petals or perianth or free.

d. The Pistil or Pistils. In the center of the flower arising from the center of the receptacle is the pistil, which is usually formed by the fusion of a number of *megasporophylls* or *carpels.* In most flowers, however, the fusion of the carpels is so complete that the separate carpels cannot be recognized. The pistil consists of an enlarged basal portion called the *ovary,* which is continued

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into a stalk or *style* on top of which is the *stigma*. The stigma is sometimes divided into a number of lobes corresponding to the number of carpels and the ovary is often similarly lobed. It is on the stigma that the pollen is received by the pistil.

Typically the receptacle is convex or flat and the ovary is attached in the center and rises above it. The ovary is then said to be *superior* and the flower *hypogynous* (*hypo*, below, *gynous* referring to the ovary). The outer portion of the receptacle may however grow up and around the ovary, so that the latter seems to lie at the bottom of a cup from the edges of which the other whorls of floral leaves arise. In this case the ovary is said to be half inferior and the flower is said to be *perigynous* (*peri*, around). In still other cases the receptacle may not only grow up and around the ovary but may actually fuse with it so that the outer whorls of floral leaves seem to arise from the top of the ovary. The ovary is then said to be *inferior* and the flower *epigynous* (*epi*, upon, or on top of).

Make a longitudinal section of the flower by cutting vertically through the axis of symmetry, including the axis of the pistil. This will enable you to determine whether the ovary is superior or inferior and whether the flower is hypo-, peri-, or epi-gynous.

QUESTION: Record the number of pistils in the flower, whether the pistil is composed of one or more carpels, whether the ovary is hypo-, peri-, or epi-gynous.

Draw the longitudinal section, making your drawing about 75 mm. across.

e. The Floral Diagram.

Draw a floral diagram, i.e., a diagrammatic cross-section of the flower passing through the calyx, corolla, stamens, and ovary, about 75 mm. in diameter, using the information obtained in your study of the flower.

C. The Pollen Sacs (Microsporangia) and Pollen (Microspores).

a. In the prepared slide containing a cross-section of a lily anther, identify the *pollen sacs* containing the *pollen grains*, and in the center the vascular bundle, which in the complete stamen passes down through the filament. Study some of the pollen grains and notice that many of them contain two nuclei. The single nucleus of the microspore has divided to form a *tube nucleus* and a *generative nucleus.*

QUESTION: Of which generation is this the beginning?

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Draw the cross-section making your drawing 75 mm. across.

b. Drop some pollen grains from the anther in a drop of 10% sugar solution on a slide. Keep the slide moist and examine every 30 minutes for growth of the pollen tube.

Question: To which generation does the pollen tube belong?

Draw some pollen grains and a pollen tube.

D. Transverse Section of an Ovary. On the prepared slide of a lily ovary, note the triangular shape of the section due to the ovary being formed by the fusion of three carpels. Corresponding to the three lobes note the three cavities, in each of which are two *ovules.* The ovules are attached to the central portion of the section (axial placentation). Note the *inner* and *outer integuments,* and the *micropyle.* In the center of the ovule is the *embryo sac* or *female gametophyte.* This is filled with relatively clear protoplasm and will contain one or more nuclei. Surrounding the embryo sac is a single layer of cells which represent the *nucellus* or *megasporangium.*

Question: To which generation does the embryo sac belong?

Draw the whole section in outline making your drawing 100 mm. in diameter and drawing one ovule in detail.

E. The Fruit. Botanically a *fruit* is a mature ovary with its contained seeds and any parts of the flower closely associated with it. Used in this way it is seen that the term includes many plant products which would not in ordinary language be called fruits, such, for example, as the pea pod or the bean pod.

a. Pod of Bean or Pea. Study the pod of the bean or pea. The pod is developed from the ovary of the bean or pea flower. It is formed from a single carpel (megasporophyll). Identify the remnant of the calyx of the flower in which the fruit was developed.

QUESTION: Was this fruit developed from a flower with a superior or an inferior ovary?

At the opposite end of the pod look for the old style. Because the pod is developed from a single ovary it is called a *simple* fruit. In the ripe fruit the wall of the ovary becomes the *pericarp.* The pods of the pea and bean are called *dry fruits* because the pericarp is relatively dry and not fleshy. The pea and the bean pods are also called *dehiscent fruits* because when ripe they break open of their own accord and liberate the ripe seeds, in this case the peas or beans.

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Draw a side view of a pea or bean pod showing the structures identified, making your drawing about 100 mm. long.

Open the pod by splitting it lengthwise and removing one-half. The seeds inside are enlarged ovules.

QUESTION: How and where are they attached to the carpel?

The short stalk by which the seed is attached is called the *funiculus*.

Draw a side view of the interior of the pea or bean pod, making your drawing about 100 mm. long.

b. Corn. Observe some corn on the cob. In the beginning the whole ear of corn was really an inflorescence or group of flowers. Where each grain of corn now is, was a flower. Each grain was developed from a single separate ovary and is therefore a simple fruit. A small remnant of the style can be seen projecting from the upper end of each grain.

Examine a grain of corn. As already stated this is the fruit.

Question: Is it a dry or fleshy fruit?

The pericarp is firmly united with the seed coats and can scarcely be distinguished from them. The fruit does not break open when ripe and is therefore said to be *indehiscent.* The short stalk by which the grain was attached to the cob is the stalk of the flower or *pedicel.*

Draw an external view of a grain of corn, making your drawing 40 mm. long.

c. A Plum. Study a fresh plum or a prune, which is really a dried plum. The latter should have been soaked overnight in water. This is an example of a fleshy fruit which contains a "stone." The seed is inside the stone, as may be seen by breaking the latter open. The pericarp forms both the outer fleshy layer and the inner stony layer surrounding the seed.

Draw a diagrammatic cross-section of a plum.

d. An Apple. Study a ripe or nearly ripe apple. The fruit was formed from the ovary and receptacle of a single flower. Note the stalk and at the opposite end look for the remains of the calyx, stamens, and styles.

Question: Was the ovary from which the apple developed superior or inferior?

Question: Was the flower hypo-, peri-, or epigynous?

Make a longitudinal section through the axis of the apple extending from the stalk to the remnant of the calyx. Make a cross-section of one of the halves by cutting at right angles to the cut already made. Note the division into an outer fleshy portion and an inner papery "core" within which are the seeds. Only the portion of the "core" immediately surrounding the spaces in which the seeds lie is formed from the walls of the ovary. The rest of the "core" and all of the fleshy portion is formed by the receptacle.

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Draw a longitudinal section of an apple, 60 mm. across.

F. Seeds. A seed is a ripened ovule. A fruit may contain one or more seeds according as one or more ovules reach maturity.

a. A Bean Seed. Examine a bean seed which has been softened by soaking in water. Note that it is covered by a smooth, pale, leathery membrane called the *testa* or seed coat. On one side near the middle is an oval scar, the *hilum*, which marks the place where the funiculus joined the ovule. Close to one end of the hilum can be seen a small hole, the *micropyle*, which pierces the testa. It will be remembered that it was through the micropyle that the pollen tube passed to fertilize the egg in the embryo sac in the ovule.

Draw a side view of a bean seed, making the seed 35 mm. long.

On removing the testa it will be noticed that the remainder of the seed easily splits into two parts along a plane passing through the micropyle. The two thick fleshy bodies which thus become separated are the *cotyledons*, or seed leaves. The Class Angiospermae is divided into two sub-classes, the *Dicotyledons* and the *Monocotyledons*.

QUESTION: To which of these sub-classes does the bean plant belong?

The two cotyledons are part of an embryo the rest of which will be found near the area covered by the hilum. The *cotyledons* are attached to the young stem or *plumule*. At the other end of which is the *radicle* which develops into the primary root.

Draw a side view of the split bean seed showing the parts of the embryo, making your drawing 50 mm. long.

b. A Corn Seed. Cut the corn grain in half lengthwise from the wider rounded end to the narrow pointed one and from one flat side to the other. Note the small triangular section of the embryo at the pointed end. With the hand lens distinguish the *single cotyledon* and the *plumule.* The rest of the grain is composed of the *endosperm* which develops from the embryo sac.

QUESTION: Does the corn plant belong to the Dicotyledons or the Monocotyledons?

Draw the longitudinal section of the corn grain, making your drawing 30 mm. long.

G. Germination of Seeds. Observe stages in the germination of bean seeds which have been planted in loose earth.

QUESTION: Where does the seed coat break open?

QUESTION: What part of the embryo is the first to protrude?

If an old enough seedling is available compare a cotyledon with a foliage leaf.

Draw three stages in the germination of the bean seedling.

Study stages in the germination of corn and compare with the similar stages studied in the bean.

Question: What differences do you notice between the germination of the bean and the corn?

H. The Leaf.

a. Study a leaf of the lilac or other convenient plant. Note the division into *petiole* and *blade.* How would you describe the arrangement of the *veins* in the blade. Do the veins continue into the petiole? Are *stipules* present?

Draw the leaf making the length of the blade 75 mm.

b. Strip off a portion of the surface layer (epidermis) from the lower side of the leaf blade. Mount it in water and examine under the microscope. Notice the irregular cells of which the epidermis is composed. Here and there are small slit-like openings, the *stomata.* Each *stoma* is surrounded by two *guard cells.* Compare the guard cells with the other cells of the epidermis as to shape and content.

Draw a few cells of the epidermis, including a stoma and its guard cells, making the diameter of an epidermis cell about 20 mm.

c. Study a prepared cross-section of a suitable foliage leaf. Identify the *upper* and *lower epidermis.* Compare the cells as seen in the section with the surface views already studied.

QUESTION: What is the shape of an epidermal cell?

Note the *cuticle* on the surface of the epidermis.

QUESTION: How do the guard cells appear in cross-section?

Identify the *palisade layer*, composed of one or more layers of cells just under the upper epidermis.

QUESTION: What is the shape of the cells?

QUESTION: How are they arranged?

QUESTION: Do they contain nuclei?

QUESTION: Chloroplasts?

Between the palisade cells and the lower epidermis is the *spongy tissue*, which may constitute a large part of the interior of the leaf.

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QUESTION: What is the shape of the cells of the spongy tissue?

QUESTION: Do these cells contain nuclei?

QUESTION: Chloroplasts?

Between the cells of the spongy tissue (whence the name) are irregular intercellular *air spaces.* These air spaces communicate with the outside air through the stomata, although the communication may not be evident in a single section on account of this being cut in a single plane. It is across the plasma membranes and walls of the cells of the spongy tissue that the exchange of gases involved in photosynthesis and respiration take place.

QUESTION: What advantages are there to the plant in having intercellular air spaces?

The section will also contain *veins* cut crosswise or lengthwise. The tissue of which they are composed will be studied later.

Draw a portion of the section making the thickness between the upper and lower epidermis about 75 mm. in your drawing.

I. The Stem.

a. Examine the growing tip of an *Elodea* plant and if available study a prepared longitudinal section. Identify the *embryonic region* and *region of elongation.* Note the lateral outgrowths which are the beginning of the leaves. In the angles between the stem and the older leaves look for *axillary* buds. Identify *nodes* and *internodes.*

Draw a portion of the stem and leaves five times natural size.

Draw the terminal bud, making it 25 mm. long.

b. Study *winter buds* of the elm, poplar, or some other tree. Cut lengthwise one of the more slender, tapering buds, and examine carefully with a hand lens.

Question: In general structure how does the cut surface compare with a section of the Elodea bud?

Question: Can you detect the unelongated axis, or stem?

Pry apart the outermost scale leaves.

Question: What is their function?

Note the folded greenish leaves within.

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Question: Are the green leaves attached to the axis above or below the scale leaves?

Question: Why is such a bud spoken of as a dormant bud?

Draw a longitudinal section of a bud ten times natural size.

c. When rapid growth of the tree is resumed in the spring, the outer scale leaves (bud scales) expand somewhat, but soon fall off, leaving a group of small scale-leaf scars (bud-scale scars). The internodes of the bud elongate, and the greenish leaves expand rapidly to their mature size. Thus a leafy branch is developed. New buds soon appear in the axils of the expanded leaves.

Examine a fairly large twig or branch. Locate the group of scale-leaf scars nearest the tip of the stem. These scars represent the position of a bud a year ago, and therefore the portion above the scars has developed within the last season of growth.

Question: By locating other groups of scale-leaf scars determine the age of older parts of the twig.

Make an outline drawing of twig natural size showing two years' growth.

d. Study a prepared slide of a cross-section of a one-year-old *stem of Aristolochia*, beginning at the periphery and working inward. A single layer of cells, the *epidermis*, forms the outer covering of the stem. The outer walls of the epidermis cells are thickened.

QUESTION: Of what advantage is this to the plant?

Inside the epidermis is a layer, several cells in thickness, in which the cells, rectangular in shape, are thickened at the corners. This kind of tissue is called *collenchyma.*

QUESTION: What would you surmise to be its function?

Next comes a layer, also several cells in thickness, of thin walled parenchyma cells, polyhedral in outline. Since in the living plant these cells contain chlorophyll the tissue is called *chlorenchyma.*

QUESTION: What would you conclude to be one of the functions of these cells?

Within the chlorenchyma is a second layer of thick walled cells. The walls of the cells are uniformly thickened. These cells are much elongated in the direction of the length of the stem and are called *bast fibres.* The tissue which they compose is a form of *sclerenchyma.* Within the circle formed by the bast fibres in section is a second layer of *parenchyma.* In this parenchyma, like a series of large dots in a circle, are the cross-sections of the *vascular bundles.* Connecting the separate vascular bundles and extending through them so as to form a circle in the section is a layer of thin walled flattened cells. These cells make up the *cambium.* The portion of the

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cambium within the vascular bundles is called the *fasicular cambium,* that between the bundles the *interfasicular cambium.* The cells of the cambium are in active growth and cell division, giving rise to new cells on both their outer and inner surfaces.

QUESTION: What evidence do you find of this active growth in your section?

The portion of the vascular bundle outside the fasicular cambium contains the *phloem.* Look carefully with the high power and try to distinguish the phloem cells from the surrounding parenchyma.

QUESTION: Do the phloem cells contain protoplasm?

Towards the center from the fasicular cambium are the large thick-walled cells of the *xylem.*

QUESTION: Do they contain protoplasm?

The largest of these cells towards the cambium will probably be xylem vessels. Look carefully with the high power at the extreme central portion of the xylem for the protoxylem, composed of small thick walled cells. This is a *primary tissue* formed from the primary meristem. The xylem and the phloem are *secondary tissues* formed from the cambium.

The central portion of the section is occupied by the *pith,* composed of parenchyma cells. The portion of the pith extending outward between the vascular bundles forms the *pith rays.*

Draw an outline showing the general features of the section about 100 mm. in diameter labeling all structures identified.

Draw a portion of the section extending from the epidermis and passing through a vascular bundle to the protoxylem and pith, making the distance from the epidermis to the pith 100 mm., showing the cells in detail.

e. The leafy shoots provided have stood for some time in a solution of eosin. Cut across the stem *very near* the end which was in the solution.

QUESTION: Is the stain uniformly distributed over the section?

QUESTION: In what part of the stem is most of the color?

Cut sections slightly further up the stem and trace the path of the colored liquid. *Draw* a diagram showing the result of this experiment.

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f. Study a prepared section of a two- or three-year-old stem. Identify the structures studied in the cross-section of the younger stem. *Cork* has developed and now forms the outer layer. In the xylem note the differentiation into *spring wood* with larger and thinner walled cells and *summer wood* with smaller and thicker walled cells. It is this differentiation in the size and thickness of the walls of the cells which gives rise to the annual rings.

QUESTION: How old was the stem from which this section was cut?

Draw the section in outline showing besides the other structures the annual rings, making your drawing 75 mm. in diameter.

J. The Root.

a. Mount two or three germinated grass seeds in water on a microscopic slide and cover with a cover-glass. Study the different regions of the root beginning at the tip.

The extreme tip of the root is occupied by the *root cap.* The outer cells of the root cap are torn off and broken up and give the root tip a slimy slippery surface as it is forced into the ground. The root cap is conical in shape and covers the *embryonic region* of the root which is easily recognized on account of being composed of small cells with dense protoplasm. The cells of the embryonic region give rise to the cells of the root cap on the one hand and the tissues of the root on the other.

Immediately above the embryonic region is the *region of elongation,* in which the cells are growing especially in length, and in which cell division is rare. This region is more nearly transparent than the embryonic region. By focusing carefully observe the differentiation into the outermost layer (*epidermis*), the *cortex,* just within and the *central cylinder* or *stele* in which many of the cells are much elongated. In the older part of this region note the *root hairs.*

Question: What is the relation of the root hairs to the epidermis?

Above the region of elongation is the *region of cell differentiation* in which the cells of the epidermis, cortex, and stele are beginning to show more marked differentiation. The walls of some of the cells of the stele may show spiral thickenings.

Next follows the *mature region* in which the cells have become completely differentiated in form and structure.

Draw the entire portion of the root studied, showing the different regions, making your drawing 100 mm. long.

b. Study a prepared slide of a cross-section through the mature portion of a young *Ranunculus* (*buttercup*) *root.* This section shows mainly primary tissues, that is, tissues which had their origin in the embryonic region of the root tip. Examine the tissues, beginning at the outer surface and compare the general arrangement and cellular structure with that of the stem already studied.

The *epidermis* is a single layer of thin walled cells, from some of which *root hairs* may extend outward.

Under the epidermis and occupying a large portion of the section is the *cortical parenchyma,* composed of large thin walled irregular cells, separated in places by *intercellular spaces.*

Within the cortical parenchyma and forming the inner boundary of the *cortex* is the *endodermis,* composed of cells, rectangular in outline.

Question: Are the cells of the endodermis all alike so far as the thickness of their walls is concerned?

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QUESTION: If not, what relation does the thickness of the cell walls bear to the other structures in the root?

The portion within the endodermis is called the *stele.* Forming the boundary of the stele and lying next the endodermis is the *pericycle,* consisting of one or more layers of thin walled cells.

The arrangement of the *phloem* and *xylem* in the root is different from that in the stem. Bundles of small thin walled phloem cells alternate with bundles of large thick walled xylem cells in a circle.

Between the xylem and phloem bundles are thin walled *parenchyma cells.* It is from these cells that the cambium later is developed in a layer passing outside the xylem and inside the phloem.

Draw the entire section in outline about 75 mm. in diameter, showing the arrangement of the various tissues.

Draw on a larger scale so as to show the structure of the individual cells a portion of the section extending from the center to, and including, the endodermis.

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XI. THE PROTOZOA

The Phylum Protozoa

A. The phylum Protozoa is divided into four classes as follows:

Class *Sarcodina*, locomotion by means of pseudopodia. Example: Amoeba.
Class *Mastigophora*, locomotion by means of flagellae. Example: Trypanosoma.
Class *Infusoria*, locomotion by means of cilia. Example: Paramecium.
Class *Sporozoa*, non-motile, parasitic forms. Example: Plasmodium.

Examples of the first and third classes have been studied.

B. Plasmodium (the Malarial Parasite). Study prepared slides made by staining films of blood from malarial patients. Within the corpuscles may be found *trophozoits* in various stages and the beginning of *merozoit formation.* Preparations showing the micro- and macro-gametocytes are rare. It is usually not possible to provide material for class study of the stages passed in the mosquito.

Draw several stages of the malarial parasite in human blood.

C. Volvox.

a. If fresh material is available examine with the naked eye colonies swimming in a glass vessel and in a watch glass or hollow slide under the microscope. Each colony consists of a large number of flagellated cells arranged on the surface of a gelatinous sphere. Focus on the edge of this sphere and study the individual cells. Note the *eye-spot* or *stigma* in each.

Question: How many *flagellae* has each cell?

Question: How are the cells connected together?

Draw a few cells showing structures observed.

Daughter colonies, *parthenogonidia*, may be present. If so, examine them and compare with the parent colony.

Draw one or two parthenogonidia.

Sexual reproduction may be in progress. The *ova* are developed from individuals called *macrogonidia* which become enlarged and move from the surface to the interior. Other individuals become disc-shaped *microgonidia* and develop into numerous sperms.

Draw macrogonidia and microgonidia if present.

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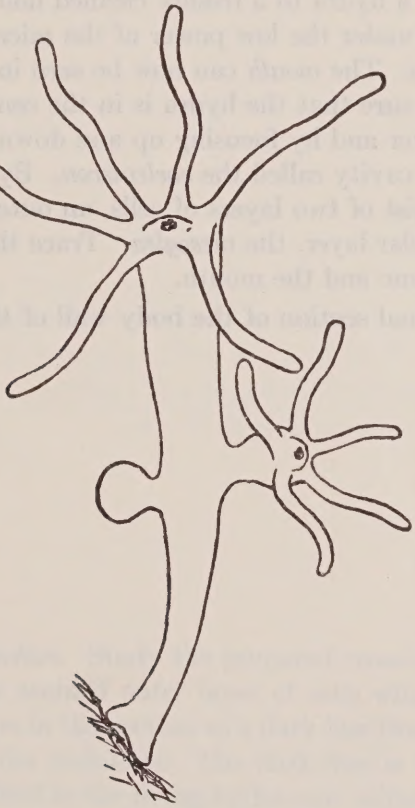
XII. COELENTERATES

1. Hydra

A. Movements and Reactions. Note the small objects, about two to ten millimeters in length according to degree of expansion, in the watch glass. These are individuals of hydra. If the hydra are green, place a piece of white paper under the watch glass; if they are brown, use the black table top as a background for observing them. Place the watch glass in a convenient position with good light and avoid moving or jarring the watch glass after it has once been placed in position.

Examine the hydra with a hand lens and observe its elongated cylindrical *body* at one end of which a number of *tentacles* are attached in a circle surrounding a conical region called the *hypostome.* The other end is usually attached and called the *foot.*

Label the printed drawing of an expanded hydra.



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HYDRA

QUESTION: Describe what happens when one of the tentacles of an expanded hydra is touched with the tip of a needle.

Place a small fragment of a crushed snail in the water in the watch glass and by means of a needle gently bring the fragment in contact with one of the tentacles of the hydra.

Question: How does the hydra take in its food?

Gently shake the watch glass and observe how the hydra attaches itself to the watch glass.

Question: By what part of its body does the hydra attach itself?

Hydra reproduces by budding. Examine your specimen for buds in various stages of development.

B. Microscopic Examination of the Entire Animal.

a. With a pipette transfer a hydra to a freshly cleaned hollow slide, add a drop of water but no cover-glass, and examine under the low power of the microscope. Observe again the structures seen with the hand lens. The *mouth* can now be seen in the center of the hypostome.

Add a cover-glass making sure that the hydra is in the center of the depression in the slide. Continue to use the low power and by focusing up and down on the hydra determine that the body is hollow, containing a cavity called the *coelenteron.* By focusing on the edge of the body wall this can be seen to consist of two layers of cells, an outer *ectoderm* and an inner *entoderm,* separated by a thin non-cellular layer, the *mesoglea.* Trace the two cellular layers out into the tentacles and to the hypostome and the mouth.

Draw an optical longitudinal section of the body wall of the hydra, showing the structures as observed above.

b. Nematocysts. Focus with the low power on the ectoderm as seen in optical section and observe the groups of *nematocysts,* particularly abundant on the tentacles. These are small pear-shaped bodies contained in special cells called *cnidoblasts.* Projecting from each cnidoblast is a fine hair-like protoplasmic process called the *cnidocil.* This can usually be seen by carefully adjusting the light by means of the diaphragm. The nematocyst contains a long coiled *thread,* which is thrown out when the cnidoblast is stimulated. This can be done by adding a drop of

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Methyl Green solution (see Appendix) on one side of the slide and allowing it to run under the cover-glass. There are two kinds of nematocysts, one kind has barbs at the base of the hair, the other is without these barbs.

Draw a nematocyst before and after the extrusion of the stinging thread, showing in the latter case the barbs. Make the pear-shaped part of the nematocyst about 15 mm. long.

c. Study of a Prepared Cross-Section. Study the prepared cross-section through the body of a hydra. Identify the more deeply stained outer layer of cells which form the *ectoderm.* These cells are separated by what appears in the section as a dark line from the less densely stained and vacuolated cells which compose the *endoderm.* The dark line is the *mesoglea.* The endoderm surrounds a cavity already identified in the living hydra and called the *coelenteron.* It may contain partially digested food materials. Continue the study using the high power of the microscope. The *nuclei of the ectoderm cells* are at their inner ends near the mesoglea. They can be clearly seen as ovoid deeply staining bodies, containing granules of chromatin. The outer portions of the ectoderm cells appear to be densely granular. The cell membranes separating the cells of the ectoderm run irregularly at right angles to the outer surface.

The *cells of the endoderm* are much larger than those of the ectoderm. They contain large vacuoles and stain faintly. Their *nuclei* are similar to those of the ectoderm cells.

The cells of the ectoderm and endoderm are not all of the same kind. The differentiation of the different kinds, however, requires special preparations.

Draw the section making it 75 mm. across, filling in the details of the cells in a small part of the drawing only.

d. Male Reproductive Organs. Study under the low and high power a prepared cross-section through the *testis* of a hydra. Note that the testis is located in the ectoderm. The testis is filled with densely staining nuclei, a sperm being mostly nucleus.

Draw a section of a testis showing details of cells.

e. Female Reproductive Organs. Study under the low and high power a prepared cross-section through the *ovary* of a hydra. Note that like the testis the ovary is also developed in the ectoderm. Identify the rounded *egg cell* with a relatively large nucleus.

Draw the ovary showing details of cells.

2. OBELIA

Examine a prepared slide of Obelia, first with a hand lens for general features and then with the low power of the microscope. Identify the *polyps* and the *coenosarc.* There are two kinds of polyps, vegetative and reproductive.

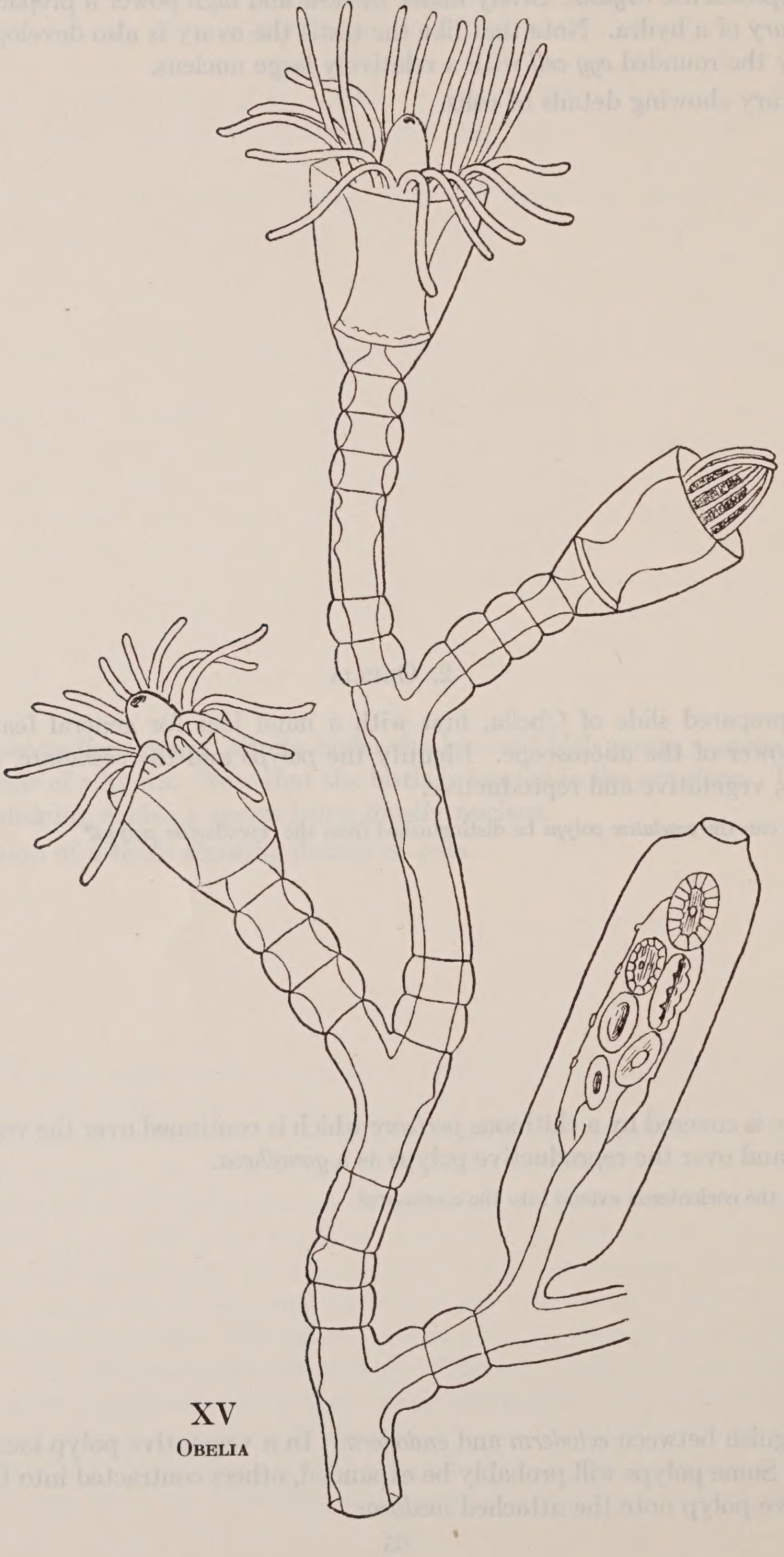
QUESTION: How can the *vegetative polyps* be distinguished from the *reproductive polyps?*

The coenosarc is covered by a chitinous *perisarc* which is continued over the vegetative polyps as a *hydrotheca* and over the reproductive polyps as a *gonotheca.*

QUESTION: Does the coelenteron extend into the coenosarc?

Try to distinguish between *ectoderm* and *endoderm.* In a vegetative polyp locate the *tentacles* and the *mouth.* Some polyps will probably be expanded, others contracted into the hydrotheca. In a reproductive polyp note the attached *medusae.*

Label **on the printed outline the structures identified in the preparation.**



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OBELIA

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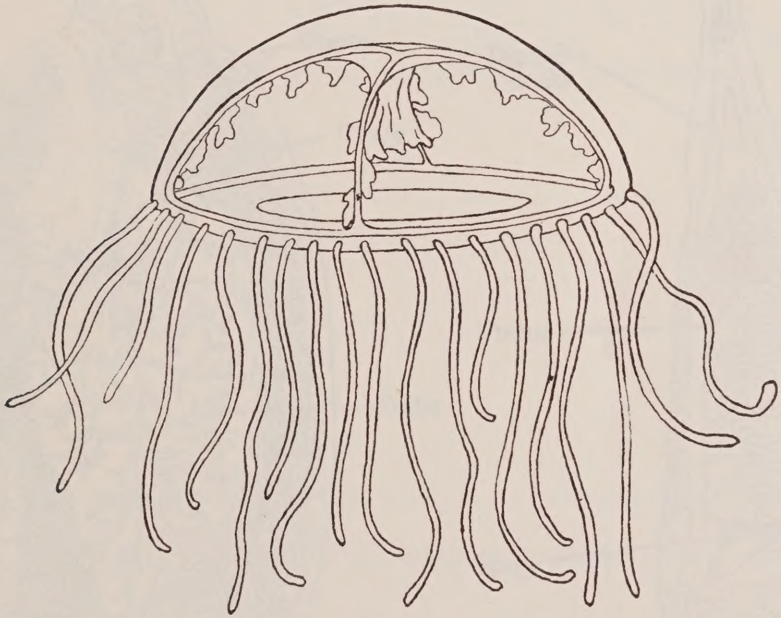
QUESTION: Briefly give the life cycle of Obelia.

3. GONIONEMUS

Examine a specimen of Gonionemus floating in a watch glass. Identify the *exumbrella* and *subumbrella* surfaces, *tentacles*, *manubrium*, *velum*. Turn the animal over and locate the *mouth*, *stomach*, and *radial canals*.

Label the structures seen on the printed outline.



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GONIONEMUS

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XIII. FLATWORMS AND ROUNDWORMS

1. Flatworms

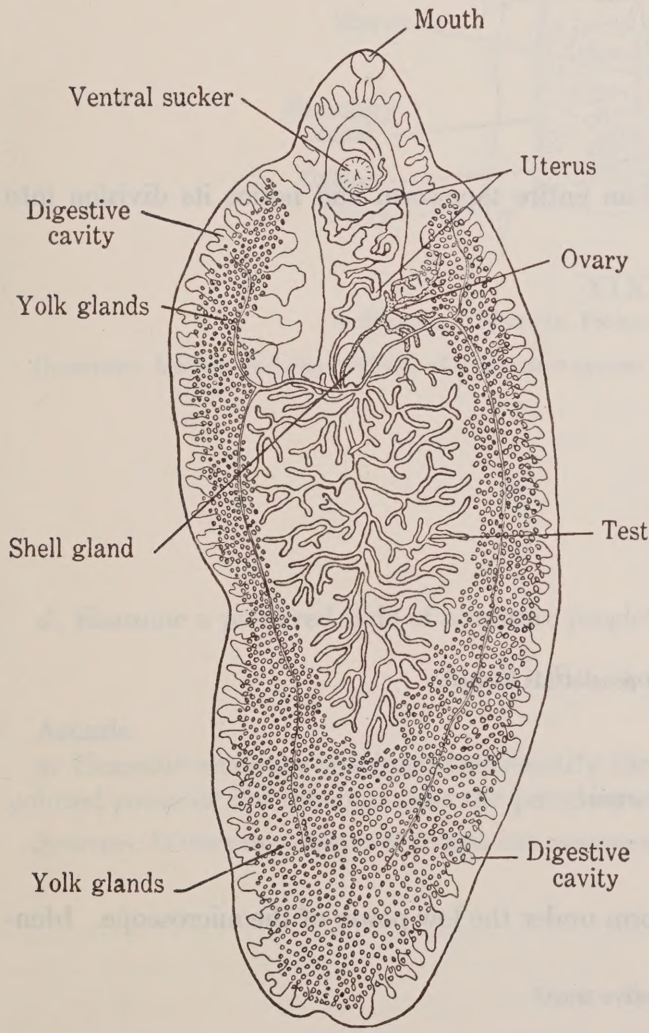
A. A Planarian. Examine a living planarian swimming in water in a watch glass. Identify *anterior*, *posterior*, *dorsal*, and *ventral surfaces*. Note the pair of *eye-spots*.

Question: Is the animal bilaterally symmetrical?

Place a small piece of meat in the watch glass and watch for the protrusion of the muscular pharynx.

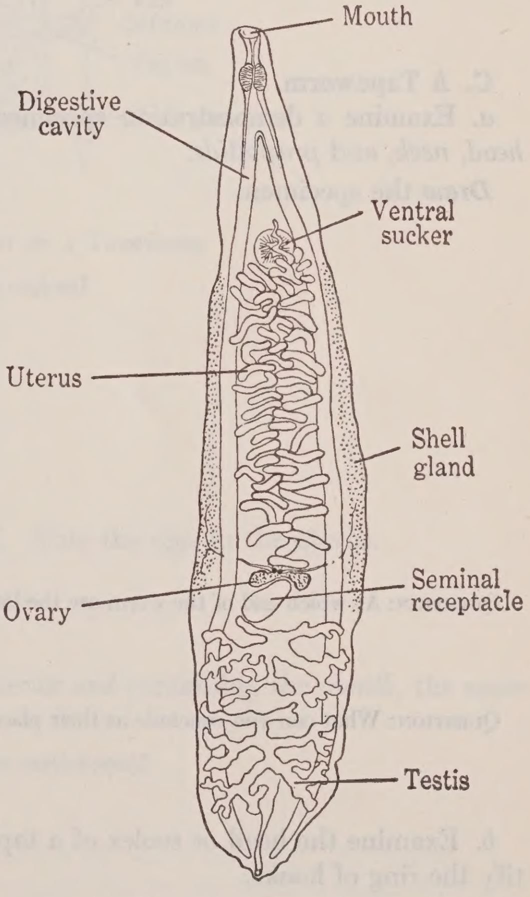
B. A Fluke.

a. Examine *Fasciola hepatica*, the liver fluke of sheep or *Clonorchis sinensis*, a liver fluke of man in Asia. Identify the *anterior sucker*, in the center of which is the *mouth* and the *ventral sucker*.


Mouth
Ventral sucker
Uterus
Digestive cavity
Ovary
Yolk glands
Testis
Shell gland
Yolk glands
Digestive cavity

XVII

Fasciola hepatica, the Liver Fluke of the Sheep


Mouth
Digestive cavity
Ventral sucker
Uterus
Shell gland
Seminal receptacle
Ovary
Testis

XVIII

Clonorchis sinensis, the Chinese Liver Fluke *b.* If available study a prepared slide of *Fasciola hepatica* or *Clonorchis sinensis* under the low power of the microscope and identify the internal organs with the aid of the printed diagrams. Both male and female reproductive organs are present and together they occupy a large part of the interior of the animal.

QUESTION: Is there a coelom?

c. If available study slides showing *cercaria* or other stages in the life cycle.

C. A Tapeworm.

a. Examine a demonstration specimen of an entire tapeworm and notice its division into *head, neck,* and *proglottids.*

Draw the specimen.

QUESTION: At which end of the worm are the largest proglottids located?

QUESTION: What can you conclude as their place of origin?

b. Examine the head or scolex of a tapeworm under the low power of the microscope. Identify the ring of hooks.

QUESTION: Is there any evidence of a mouth or digestive tract?

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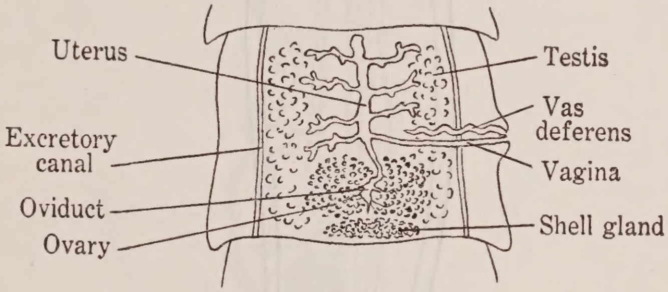
Draw the head.

c. Examine a prepared slide of an immature proglottid. Identify reproductive organs and excretory organs with the aid of the printed diagram.


Uterus
Excretory canal
Oviduct
Ovary
Testis
Vas deferens
Vagina
Shell gland

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A Sexually Mature Proglottid of a Tapeworm

Question: Do you find any evidence of a digestive system or a coelom?

d. Examine a prepared slide of a mature proglottid. Note the *eggs* in the uterus.

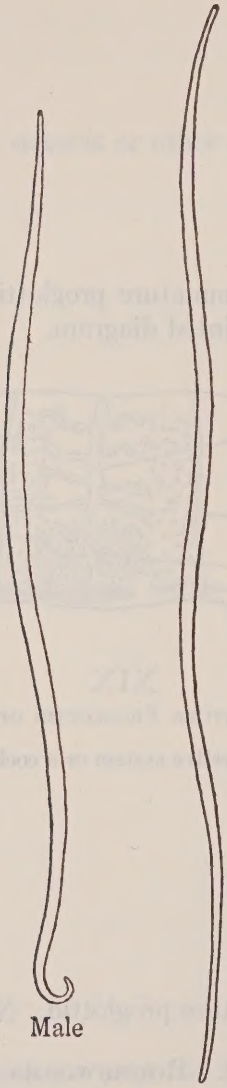
2. ROUNDWORMS

Ascaris.

a. Examine an entire specimen and identify the *anterior end* containing the *mouth*, the more pointed *posterior end* the *anus* near the posterior end.

Question: Is there any evidence of division into metameres (see earthworm)?

Label the structures listed (see previous page) on the printed outline.



XX

Ascaris lumbricoides, a Roundworm

b. Dissection. Open the worm by a dorsal longitudinal cut from end to end, being careful not to cut into the internal organs, and pin out in a dissecting dish. Identify the *digestive tract* extending from the mouth to the anus, and the reproductive organs. The sexes are separate. In the male there is a single thread-like testis which connects by a series of ducts with the cloaca. In the female paired ovaries connect each through a separate uterus with a common vagina which opens to the exterior by a genital opening.

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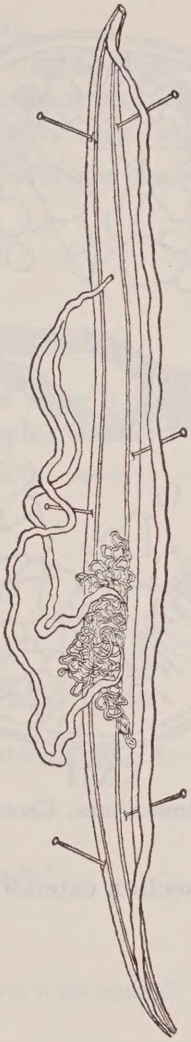
Label **the structures seen on the printed outline.**



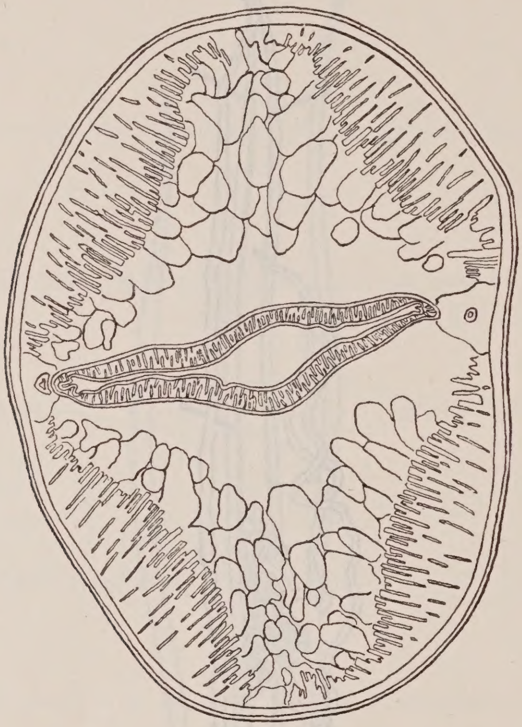
XXI

ASCARIS LUMBRICOIDES, A ROUNDWORM DISSECTED

QUESTION: Is there any evidence of an internal division into metameres (see earthworm)?

c. Cross-Section. Study a prepared slide containing a cross-section of Ascaris.

Label the following structures in the printed outline: *cuticle, epidermis, muscle cells, lateral line, excretory tube, intestine, body cavity, dorsal line,* and if present *testis* or *ovary.*



XXII

Ascaris lumbricoides, Cross-Section

Draw in more detail a portion of the section extending from the intestine to the cuticle.

XIV. SEGMENTED WORMS

1. THE EARTHWORM

A. External Features and Movements.

a. Examine a living earthworm as it crawls about in the dissecting dish. Distinguish the *anterior end,* which is conical and usually thrust forward in crawling. Note how the body changes in shape as the worm crawls. Pick out a few segments and watch those continuously.

QUESTION: Describe the method by which the earthworm crawls over the ground.

Take the earthworm in the hand and draw it through the fingers. The scratchy feeling is caused by small teeth-like projections called setae.

QUESTION: On which side of the earthworm are the setae?

QUESTION: How do the setae aid in locomotion?

QUESTION: Have you ever tried to pull an earthworm out of its hole? If so why was it difficult to do so?

QUESTION: Is the surface of the body dry or moist?

QUESTION: Of what advantage to the earthworm is the mucus?

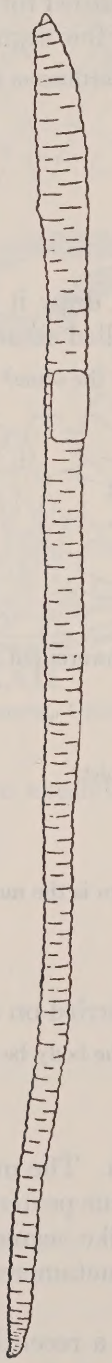
The respiration of the earthworm is carried on over the entire surface of its body.

QUESTION: Is it necessary that the surface of the body be moist for this purpose?

At the anterior end identify the *mouth.* The mouth is covered dorsally by a rounded lip-like projection, the *prostomium.* At the extreme posterior end is a round opening, the *anus.* The body of the earthworm is divided into ring-like segments called *metameres.* Somewhat toward the anterior end of the earthworm, certain metameres are enlarged, forming a glandular ring called the *clitellum.*

b. The study should be continued on a recently killed or preserved earthworm. Count the number of metameres beginning at the anterior end (the prostomium is not to be counted as a metamere). Determine the numbers of the segments which form the clitellum. On the ventral side of segment fifteen can be seen a pair of openings with swollen lips. These are the *openings of the vasa deferentia* which carry the sperm. On the ventral side of segment fourteen not far from the openings of the vasa deferentia are the openings of the oviducts. Look for the latter with a hand lens. The openings of the *seminal receptacles* between metameres 9 and 10, and 11 and 12 are difficult to see.

Label the printed drawing and add the details of structure you have been able to observe.



XXIII

Lumbricus, an Earthworm

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B. Dissection.

a. Pin out the freshly killed or preserved specimen in the dissecting dish with its dorsal side up, placing a pin at either end. Take especial care to have the dorsal side of the animal uppermost over its entire length. This may be done by observing that the ventral side is flattened and contains setae, while the dorsal side is rounded and lacks setae, and also by observing the dorsal blood vessel which shows through the body wall as a dark line along the dorsal surface. The earthworm should be pinned out so that this dark line is straight and uppermost. With scissors cut into the body wall in the median line just behind the clitellum being careful not to allow the points of the scissors to cut beyond the body wall. Continue the cut forward to the fourth metamere. The body wall surrounds a cavity or *coelom* filled with a fluid the *coelomic fluid.* Running the entire length of the earthworm and separated from the body wall by the coelom is a second tube, the *digestive tract.* In attempting to separate the body wall from the digestive tract you will discover that the latter is attached to the former by a series of thin transverse membranes. These are called *septa.* Observe the line along which a septum is attached to the inner surface of the body wall and determine the relation of this to the groove separating the two metameres.

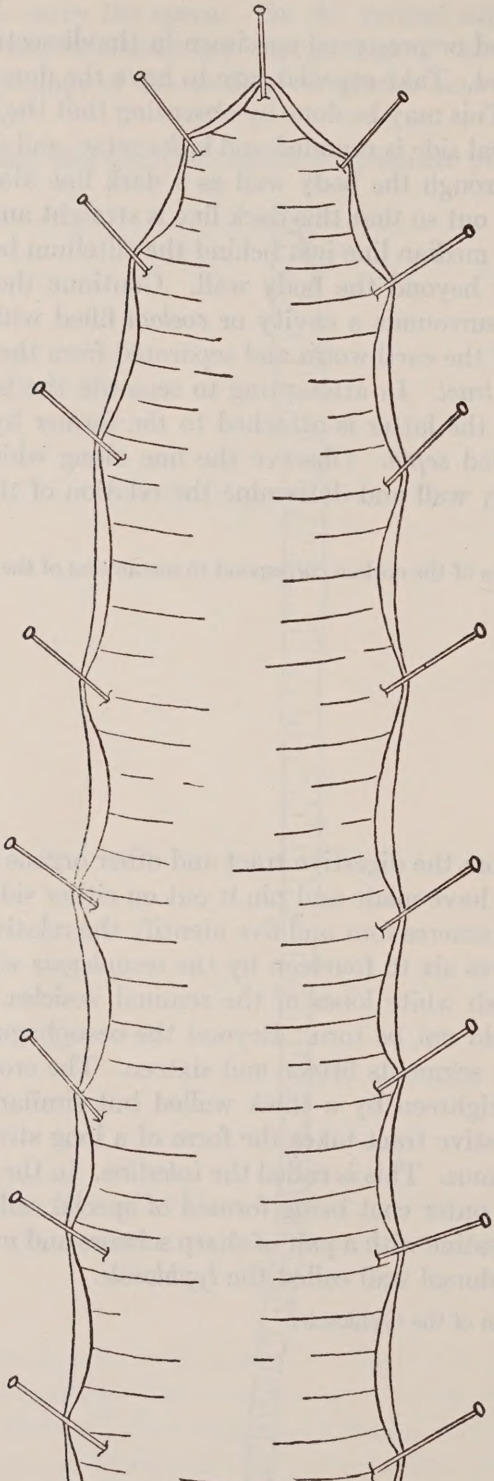
QUESTION: Do the compartments of the coelom correspond to metameres of the earthworm?

Separate the body wall from the digestive tract and other organs of the body cavity along the entire length of the cut you have made and pin it out on either side so as to expose the organs.

b. Digestive Tract. In metameres four and five identify the relatively thick muscular *pharynx.* This is followed in metameres six to fourteen by the *oesophagus* which, however, is largely obscured by the large yellowish white lobes of the seminal vesicles. The latter may be moved aside to observe it but should not be torn. Beyond the oesophagus is a large thin walled part called the *crop* which lies in segments fifteen and sixteen. The crop is immediately followed in metameres seventeen and eighteen by a thick walled but similarly shaped part, the *gizzard.* Behind the gizzard the digestive tract takes the form of a long straight tube of almost uniform diameter, extending to the anus. This is called the *intestine.* In the freshly killed worm it is yellowish in color owing to its outer coat being formed of special cells of this color, called *chlorogogen* cells. Cut into the intestine with a pair of sharp scissors and notice that it is almost entirely filled by an infolding of its dorsal wall called the *typhlosole.*

QUESTION: What is the function of the typhlosole?

Draw **a dorsal view of the digestive tract on the printed outline.**



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Lumbricus, Dissection of Digestive Tract

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c. Excretory System. The excretory system of the earthworm consists of a series of coiled tubes called *nephridia* occurring in pairs, in each metamere except the first three and the last. These tubes are attached to the septa and each one opens on the one hand into the coelom by a *nephrostome* and on the other hand to the exterior by a *nephridiopore.* They are best observed in a freshly killed specimen under water.

Draw a nephridium making your drawing 10 cm. in length.

d. The Circulatory System. Identify the *dorsal blood vessel* running along the dorsal side of the intestine. Follow the dorsal blood vessel anteriorly as it passes over the gizzard and crop. Push aside the lobes of the seminal vesicles to see it as it passes over the oesophagus. Note that as it passes over the oesophagus it gives off five pairs of large vessels, one pair to a metamere, which run around the oesophagus to its ventral side. These have been called "hearts" because they aid in pumping the blood which flows anteriorly in the dorsal blood vessel and ventrally in the "hearts." Cut across the oesophagus where it joins the pharynx and raise its anterior end to see where the hearts join the *subintestinal* vessel running posteriorly ventral to the digestive tract.

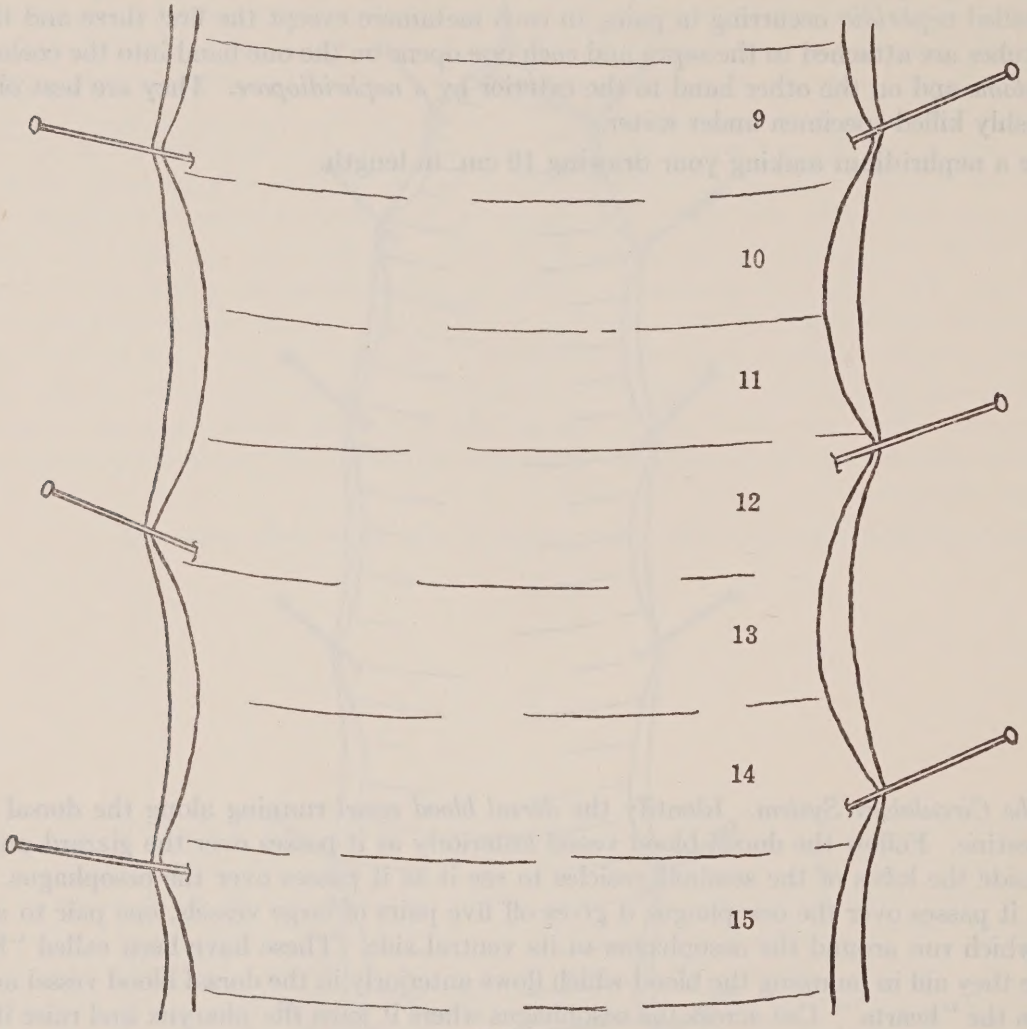
Draw in the circulatory system on your drawing of the digestive system under (*b*).

e. Reproductive System. The earthworm is hermaphroditic, i.e., each individual possesses a complete set of male and female reproductive organs. The male reproductive organs have already been encountered in the lobes of the *seminal vesicles.* Dissect away the oesophagus, already cut in tracing the blood vessels, so as to expose the seminal vesicles completely.

QUESTION: How many pairs of lobes are there?

The rest of the male reproductive organs are difficult of dissection and should be studied in a model. The female reproductive organs are also too small to be dissected by the beginning student, except the *seminal receptacles*, which receive the sperm at copulation. They are small spherical white bodies arranged in two pairs in metameres nine and ten, and attached to the body wall.

Draw in the reproductive organs in the printed outline and put in, in dotted lines, the parts which were seen only in the model.



XXV

Lumbricus, Dissection of Reproductive System

f. The Nervous System. Continue the longitudinal incision made at the beginning of the dissection into metameres three and two, and with needles carefully tease the body wall away from the pharynx, to which it is adherent, watching for a pair of minute white bodies. These white bodies are the two *suprapharyngeal ganglia,* sometimes called the "brain," although they do not correspond in any way to the brain of a higher animal. From each of these ganglia runs a *circumpharyngeal nerve cord* connecting it with a *subpharyngeal ganglion.* Under the hand lens dissect the body wall away from one side of the pharynx and follow the circumpharyngeal nerve to the *subpharyngeal ganglion.* From the subpharyngeal ganglion a *ventral nerve cord* runs under the intestine and close to the ventral body wall to the extreme posterior portion of the earthworm. Carefully remove the anterior portion of the digestive tract and the seminal vesicles so as to expose the ventral nerve cord. The ventral nerve cord consists of pairs of *ganglia,* one pair to each metamere, joined by longitudinal nerves so that the whole appears to the naked eye like a continuous cord. From each ganglion on each side arise *three lateral nerves.* Two of these arise close together near the middle of the metamere and the third near the anterior boundary of the metamere.

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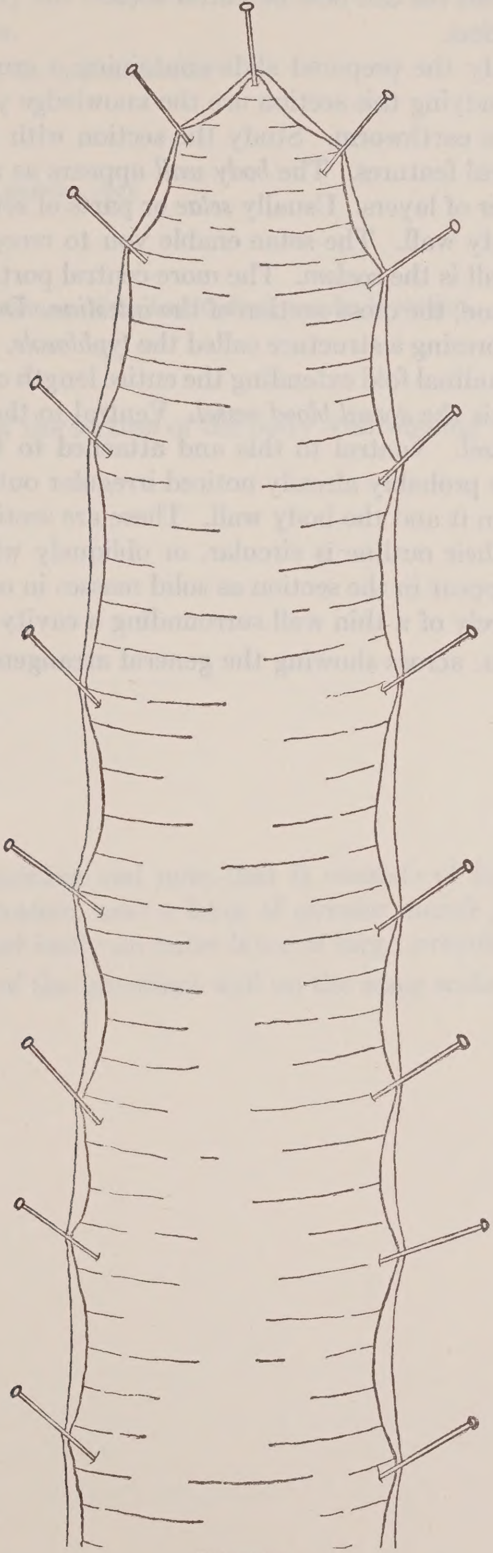
Draw, on the prepared outline, the nervous system of the first thirty segments.



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Lumbricus, Dissection of Nervous System

g. Remove a piece of the nerve cord and mount on a slide under a cover-glass and study under the low power. The lateral nerves can now be better seen.

C. Study of a Cross-Section.

a. General Features. Study the prepared slide containing a cross-section of an earthworm through the intestine. In studying this section use the knowledge you have already obtained in making the dissection of the earthworm. Study the section with the low power of the microscope and identify the general features. The *body wall* appears as a thick outer ring in the section and consists of a number of layers. Usually *setae* or parts of setae are cut in the section and can be seen piercing the body wall. The setae enable you to recognize the ventral side of the section. Within the body wall is the *coelom.* The more central portion of the section is occupied by a second inner ring of tissue, the cross-section of the *intestine.* Dorsally this ring is folded into the lumen of the intestine, forming a structure called the *typhlosole.* The typhlosole appears here in section. It is a long longitudinal fold extending the entire length of the intestine. Dorsal to the intestine and attached to it is the *dorsal blood vessel.* Ventral to the intestine and also attached to it is the *ventral blood vessel.* Ventral to this and attached to the ventral body wall is the *ventral nerve cord.* You have probably already noticed irregular outlines in the coelom on either side of the intestine, between it and the body wall. These are sections of *nephridia,* which may be either cut across when their outline is circular, or obliquely when it is oval. Occasionally portions of the septa may appear in the section as solid masses in contrast to the sections of the nephridia which consist merely of a thin wall surrounding a cavity.

Draw the section 100 mm. across showing the general arrangement of the organs.

b. Cellular Structure. Study the body wall in detail. Note the *cuticle, epidermis, circular muscles,* and *longitudinal muscles.*

QUESTION: What is the shape of the epidermal cells?

QUESTION: How do the circular muscles run?

QUESTION: Account for the appearance of the longitudinal muscles in section.

Draw in detail a portion of the section of the body wall making the distance from the cuticle to the coelom 5 cm.

Study the wall of the intestine and note that it consists of four layers: an inner layer of *epithelial cells* lining the intestine, next a layer of *circular muscle fibres,* beyond this a layer of *longitudinal muscle fibres,* and lastly an outer layer of large irregular *chlorogogen cells.*

Draw in detail a portion of the intestinal wall on the same scale as the drawing of the body wall.

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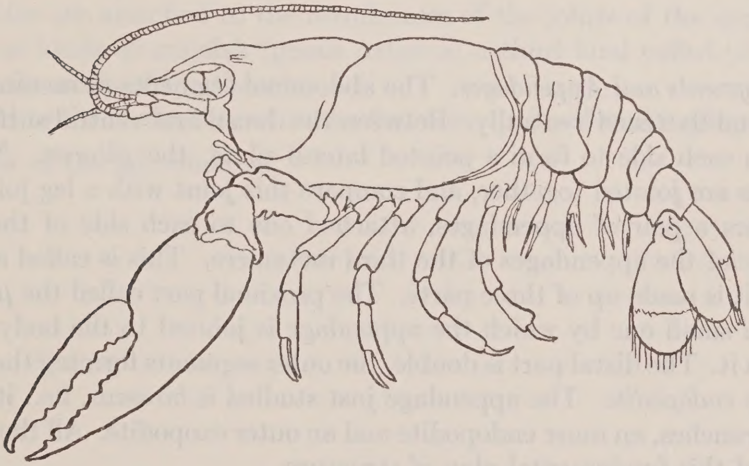
XV. ARTHROPODS

1. The Crayfish

A. External Features.

a. Study the external features on the preserved specimen. Note that the body of the crayfish is enveloped in a hard outer crust or *exoskeleton.* Movement is possible and joints occur only where this exoskeleton is soft, owing to the absence of lime salts. The body of the crayfish is divided into an anterior part, called the *cephalothorax* (cephalon—head) covered by a large continuous somewhat saddle-shaped portion of the exoskeleton called the *carapace*, and a posterior part, the *abdomen*, which is divided into six segments or *metameres* movable upon each other. The cephalothorax is continued anteriorly into a sharp pointed structure, the *rostrum.* About the middle of its length the cephalothorax is divided by a transverse groove, the *cervical groove*, into an anterior *head* and a posterior *thorax.*

Label the printed drawing.



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Gambarus, a Crayfish (Male)

b. Turn the crayfish ventral side up and observe first the *walking legs* of which there are four pairs. Note that these legs are jointed

Question: What is the meaning of the word "Arthropoda?"

Count the number of joints in one of the legs. Examine one of the joints in detail.

QUESTION: In how many directions is movement possible?

QUESTION: Just what is the structure of the joint?

Immediately in front of the walking legs are the "pincers" or *chelipeds*, so called because of the large claws or *chelae.* Examine one of the claws. Cut or break open the exoskeleton of the last segment of one of the claws and observe the attachments of the muscles which move it.

Draw the third walking leg, twice natural size.

c. Abdominal Segments and Appendages. The abdominal segments or metameres are convexly rounded dorsally and flattened ventrally. Between the dorsal and ventral surfaces the exoskeleton is produced on each side to form a pointed lateral plate, the *pleuron.* Note how the abdominal metameres are jointed together, and compare this joint with a leg joint. Each abdominal metamere bears a pair of appendages, attached one to each side of the ventral surface. Study in detail one of the appendages of the third metamere. This is called a *pleopod* or swimmeret. Note that it is made up of three parts. The proximal part called the *protopodite* consists of two segments, a small one by which the appendage is jointed to the body and a longer one extending out from it. The distal part is double, the outer segments forming the *exopodite* and the inner segments the *endopodite.* The appendage just studied is *biramus*, i.e., its distal portion is divided into two branches, an inner endopodite and an outer exopodite. All the other appendages are modifications of this fundamental plan of structure.

Draw a swimmeret, making your drawing 40 mm. long.

Study the other abdominal appendages and compare them. If your specimen is a female the appendages of the third to the fifth abdominal segments will be alike and those of the first and second abdominal segment will be similar but smaller. If it is a male the third to fifth abdominal appendages will be alike while those of the first and second will be modified to form *copulatory organs*, the two appendages of each side fitting together to form incomplete tubes which serve for the transfer of the sperm from the openings of the vasa deferentia on the first protopodite of the last walking leg to the opening of the *seminal receptacle* on the abdomen between the third and fourth pairs of walking legs of the female. The appendages of the sixth abdominal segment are flattened to form a pair of *uropods* or tail feet. The end of the abdomen is produced into a flat structure called the *telson* on which the anus opens.

d. The Gills. The carapace already observed as the covering of the cephalothorax is continued laterally on either side into a fold which corresponds in position to the pleuron of an abdominal segment. This fold is called the *branchiostegite*, or gill cover. In this way a gill chamber is formed between the inner surface of the branchiostegite and the wall of the cephalothorax which is entirely covered by the exoskeleton and outside the body proper. Carefully insert one blade of the scissors from the posterior into the gill chamber as far dorsally as it will go without tearing anything, and make a cut parallel to the middle line as far as the cervical groove and then along the groove to its anterior end. This will remove the branchiostegite of one side and expose the gills. Note the plume-like *gills* extending dorsally from the bases of the appendages. Some, called *podobranchiae* are attached to the bases of the appendages, others called *arthrobranchiae* are attached to the membranes of the joints of the appendages with the body wall. In some kinds of crayfish (genus Astacus) a third kind called pleurobranchiae are found attached to the walls of the thorax.

Gills are attached to the chelipeds and to the first three pairs of walking legs.

Draw a side view of the gill chamber.

e. Appendages of the Cephalothorax. The chelipeds and walking legs consist of protopodites and endopodites, the exopodites being absent. In front of the chelipeds the appendages are small and closely packed together round the mouth. With two needles pull these appendages aside so as to be able to see the *mouth* which they cover. The mouth opening, which is in reality rather large, is closed by a pair of *mandibles* or jaws. These work sideways instead of up and down as do those of the frog and ourselves. That the mandibles are really appendages built on the same plan as the other appendages will appear later. Between the mandibles and the pincers are five pairs of appendages which, like the mandibles, move from side to side in a horizontal plane. The three pairs which immediately precede the pincers are called *maxillipeds* (jaw-feet). Study the third maxilliped, the one which appears on the surface, with a hand lens. Note that like an abdominal appendage it is composed of two protopodites, a relatively large, flat endopodite composed of five segments and a small exopodite. This appendage bears in addition a folded plate-like segment, called an *epipodite*, attached to the first protopodite and bearing a gill (*podobranch*). Remove the *third maxilliped* from the right side by placing the tip of a sharp scalpel under the joint between the first protopodite and the thoracic wall and cutting towards you, being especially careful not to disturb the underlying appendages. The *second maxilliped* may now be studied in place with a hand lens, then removed and the *first maxilliped* similarly studied. The maxillipeds are thoracic appendages and the first maxilliped marks the beginning of the thorax.

Carefully remove the first maxilliped as directed for the third maxilliped. This will bring into view the *maxillae*, of which there are two pairs. They are without attached gills. The epipodite of the *second maxilla* is well developed and acts as a paddle to move the water which has passed over the gills out at the anterior end of the gill chamber. Carefully remove the second maxilla and study the *first maxilla* in place. The first maxilla may then be removed and the *mandible* studied. The segment which forms the jaw is really the first protopodite. The small "feeler" is formed by the second protopodite and the first and second endopodites.

The next pair of appendages in front of the mandibles are the *antennae*. They are the long feelers, nearly as long as the body, which can be moved in all directions. The basal portion of an antenna consists of two protopodites which are somewhat hidden by the folds of the carapace. The long feeler is the endopodite. The exopodite is a broad plate-like segment. In front of the antennae and attached to the first segment of the body are the *antennules*, small appendages each with two feelers, which do not seem to correspond in structural plan to any of the other appendages.

The *eyes* are on stalks which are movable. They bear certain resemblances to appendages, but are not classified as such. Observe with a hand lens in a good light the position of the darker *visual part* which is on the end of the stalk. It will be seen that it is made up of a large number of elements. Each of these elements is really a simple eye. The complete eye of the crayfish is said to be a *compound eye.*

Arrange the appendages which have been taken from the right side in order on a sheet of paper with the most anterior at the top, and take off the remaining appendages of the right side so as to have a complete set arranged on the paper.

Make a list of the nineteen pairs of appendages of the crayfish in order from anterior to posterior, and opposite each pair write the functions it performs and the modifications from the typical biramus appendage of the abdomen which it has undergone.

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List of appendages of crayfish.

f. Observations on the Living Animal. Observe a crayfish in a glass-bottomed dish over a mirror. Note the movements of the different appendages. If possible watch a crayfish feeding.

QUESTION: Which of the appendages are used in each of the three methods of locomotion, i.e., walking, swimming forward, and swimming backwards?

B. Dissection. The dissection is made from the dorsal side. Pin the animal out in the dissecting dish with this side up. Insert one blade of the scissors into the joint between the cephalothorax and abdomen where the branchiostegite joins the thoracic wall and cut forward parallel to the median line to the extreme anterior end. Do the same on the opposite side. Cut along the joint between the carapace and the first abdominal metamere and dissect away the dorsal wall of the cephalothorax, being careful not to injure the underlying organs. The body cavity or haemocoel of the crayfish is small, and the organs are closely packed in it. For this reason it is not convenient to dissect one system at a time as was done in the earthworm, but better to study the organs as they come into view in a general dissection.

a. The first organ to be identified is the *heart*, since it is the most likely to be destroyed in the further dissection. If the specimen has been injected to show the arteries the heart will be brightly colored with the injecting fluid, usually yellow or red. The heart lies in the *pericardial sinus.* In the living animal the pericardial sinus is filled with *blood.* The heart receives the blood from the pericardial sinus through three pairs of *valvular openings.* Find the dorsal pair. A number of arteries extend out from the heart and their connections should be determined before they are torn. A single median artery, the *ophthalmic artery*, extends anteriorly toward the head. A pair of arteries, the *antennary arteries*, extend anteriorly from either side of the anterior end of the heart. Extending from the posterior end of the heart is a median *dorsal abdominal artery*, and extending laterally on either side are *hepatic arteries.* From the ventral side of the heart and extending straight downwards in the dissection is the *sternal artery*, which carries blood to the appendages.

In front of the heart is the large *stomach;* the posterior portion, called the *pyloric region*, is thin walled and may be partially collapsed, while the anterior and larger portion called the *cardiac region*, although it is the further from the heart, retains its shape owing to the presence of *chitinous ossicles* in its wall. Note that both the ophthalmic and antennary arteries supply the stomach.

On either side of the stomach are the large *digestive* glands called also the *hepato-pancreas.* They pour their secretion into the pyloric region of the stomach. Note that they are supplied by the hepatic arteries.

With sharp scissors cut into the stomach and identify the ossicles of the *gastric mill.*

QUESTION: If the stomach is lined with chitin, in what part of the digestive tube would you conclude that absorption occurs?

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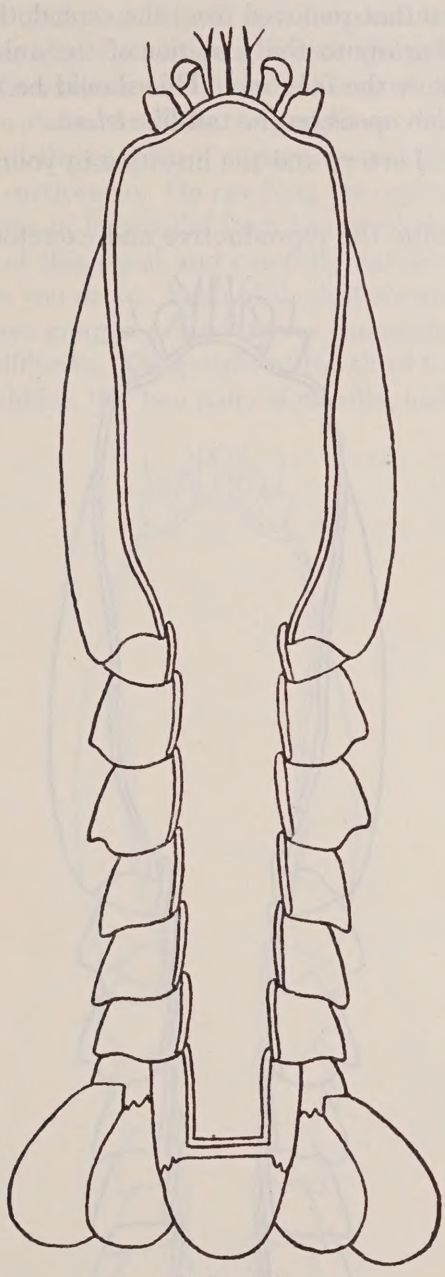
Draw in on the printed outline the portions of the circulatory and digestive systems dissected out.



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Crayfish, Dissection of Digestive and Circulatory Systems

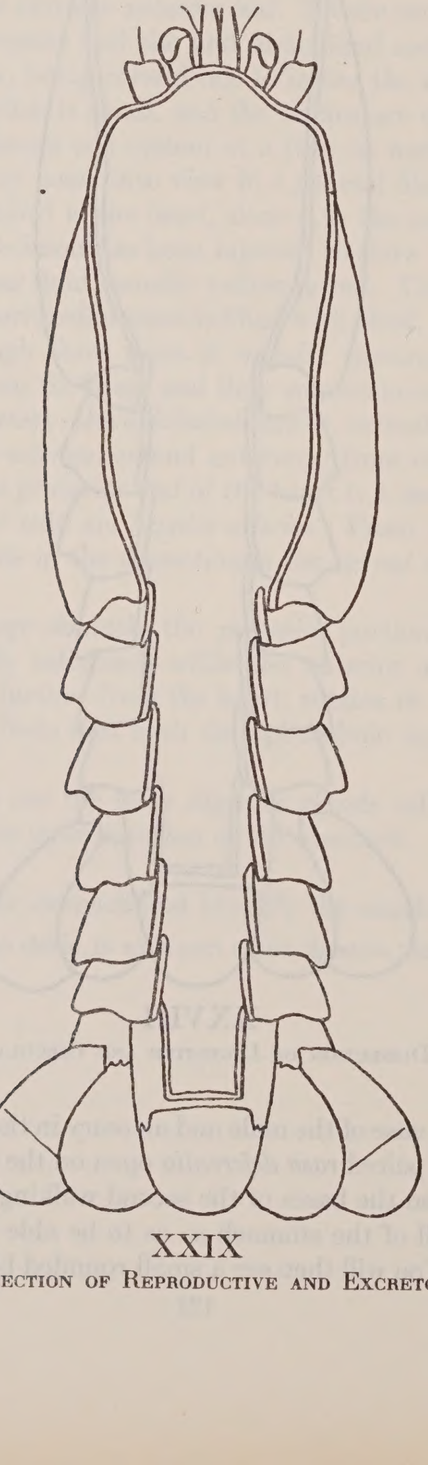
b. The gonad, a *testis* in the case of the male and an *ovary* in the case of the female, lies ventral and lateral to the heart. The paired *vasa deferentia* open on the bases of the last pair of walking legs, and the paired *oviducts* on the bases of the second walking legs not counting the chelipeds.

Push back the anterior wall of the stomach so as to be able to see into the extreme anterior portion of the body cavity. You will then see a small rounded bladder-like organ inside the base of each antenna. This is the *green gland*, also called *nephridium*, of the crayfish. It opens to the outside by a pore which can be seen on the basal segment of the antenna.

Continue your dissection into the abdomen by cutting through the exoskeleton on either side and removing a piece similar to that removed from the cephalothorax. It will now be possible to follow the *dorsal abdominal artery* to the posterior of the animal. Separate the abdominal muscles so as to be able to follow the *intestine*. This should be traced from the pyloric region of the stomach to the anus which opens on the tail-like *telson*.

Draw in the dorsal abdominal artery and the intestine in your drawing of the digestive and circulatory systems.

Draw in on the printed outline the reproductive and excretory systems of your specimen.



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Crayfish, Dissection of Reproductive and Excretory Systems

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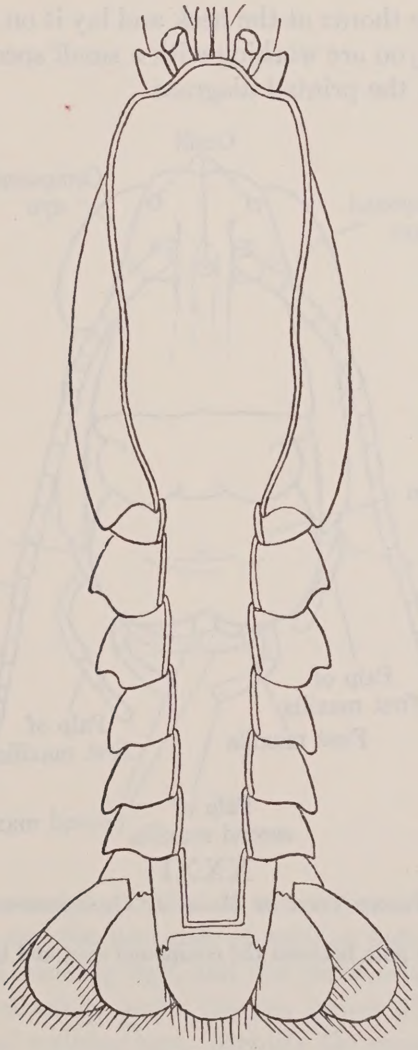
c. Nervous System. Remove the stomach, noting as you do the short vertical *oesophagus* leading to the mouth. Remove also the other organs from the cavity of the cephalothorax and the abdominal muscles from the abdomen. It will now be possible to study the *nervous system.* As in the earthworm this consists of a chain of ganglia extending the length of the body and giving off nerves to the organs in the various metameres. It is most convenient to begin the dissection of the nervous system in the abdomen where the ganglia are more easily seen. To each metamere corresponds a ganglion and the ganglia of successive metameres are connected by nerves to form a nerve chain as in the earthworm. On reaching the cephalothorax the ganglionic chain enters a canal formed by a series of ingrowths from the exoskeleton. Insert the point of the scissors into the posterior end of this canal and carefully cut away its roof a small piece at a time watching for the ganglia as you do so. Each of the last six metameres of the cephalothorax has its own ganglion. From these ganglia extend nerves connecting with the four walking legs, the chelipeds and the third maxillipeds. The ganglia of the third to the seventh metameres, viz., those corresponding to the mandibles, the two pairs of maxilla, and the first two pairs of maxilli-



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Crayfish, Dissection of Nervous System

peds, are fused into one large *suboesophageal ganglion*, which gives off nerves to these appendages and to other organs in the cephalothorax. A pair of *circumoesophageal connectives*, passing one on either side of the oesophagus, connect the suboesophageal ganglion with the *supraoesophageal ganglion* which lies in front of and therefore morphologically dorsal to the oesophagus. The supraoesophageal ganglion is sometimes called the "brain," although it does not correspond to the brain of the higher animals. From the supraoesophageal ganglion, nerves connect with the eyes, antennae, and antennules.

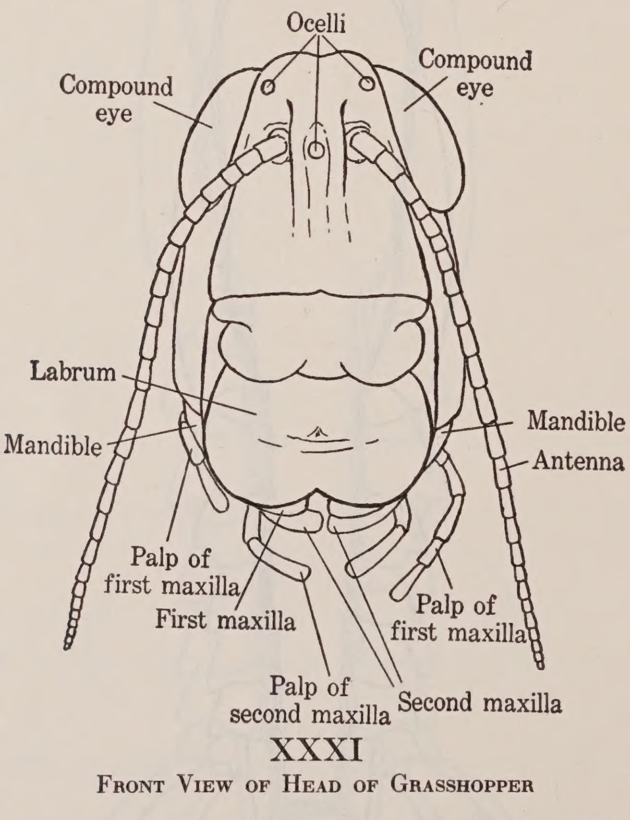
Draw in the nervous system of the crayfish on the printed outline on page 123.

2. A Grasshopper

A. External Features and Exoskeleton. Examine an entire specimen. Note the division of the body into head, thorax, and abdomen.

Question: What evidence of metamerism do you find in the thorax and abdomen?

a. Separate the *head* from the thorax at the neck and lay it on a slide so as to get a front view. Study with the hand lens or if you are working with a small species the low power of the microscope. Identify the parts from the printed diagram.


Ocelli
Compound eye
Compound eye
Labrum
Mandible
Mandible
Antenna
Palp of first maxilla
First maxilla
Palp of first maxilla
Palp of second maxilla
Second maxilla

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Front View of Head of Grasshopper

Question: What differences do you note between the compound eyes and the ocelli?

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Turn the head over and pin it down with the posterior surface uppermost. With dissecting needles carefully remove the mouth parts one at a time, beginning with the most posterior and place them in order on a slide. Named from posterior to anterior they are:

Labium, consisting of the fused second maxillae and their palps
First maxillae, with their palps
Mandibles, with their palps
Labrum, which does not contain any appendages.

Draw in order beginning with the labrum the mouth parts of one side.

b. Note the division of the *thorax* into prothorax, mesothorax, and metathorax. The *prothorax* includes the first pair of wings and the first pair of walking legs, the *mesothorax* the second pair of wings and the second pair of walking legs, and the *metathorax* the third pair of walking legs. Study one of the second pair of wings under the low power of the microscope and notice the *veins.* Examine the third pair of walking legs. Identify the *coxa* by which the leg is attached to the body, the *trochanter*, *femur*, and *tibia.* The *tarsus* contains three segments, the last having a pair of *claws* with a pad, the *pulvillus*, between them.

Draw a third walking leg.

QUESTION: What is the significance of the greater thickness of the femur in this leg?

c. Note the division of the abdomen into segments.

d. On the sides of the thorax and abdomen notice the *spiracles* opening into the trachea.

B. Internal Structure. With a pair of scissors cut through the exoskeleton from the posterior to the anterior end along a line slightly to one side of the median line, being careful not to injure the internal organs. Pin the animal out in a dissecting dish spreading the cut edges to either side. Look for the heart which lies in the median line immediately under the terga and which may have been injured. Dissect away the yellowish fat body and identify the following parts of the digestive system: *salivary glands, oesophagus, crop, proventriculus, ventriculus, gastric caeca, intestine, Malpighian tubules.*

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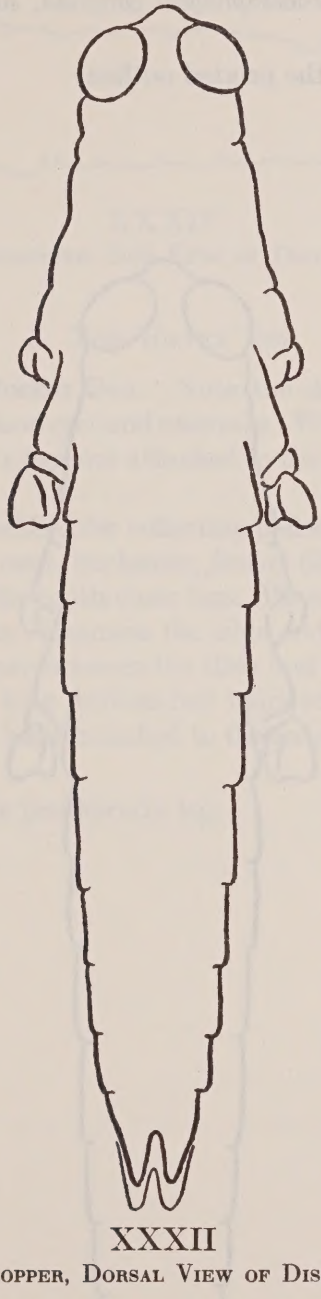
Draw in the parts identified on the printed outline.



XXXII

Grasshopper, Dorsal View of Dissection

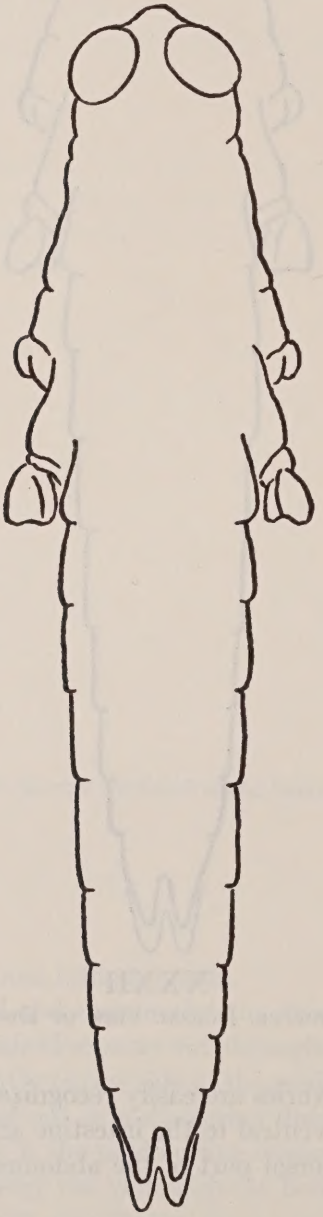
In a mature female the paired ovaries are easily recognized by the elongated oval eggs which they contain. Two oviducts pass ventral to the intestine and unite to form the vagina. In the male the paired testes lie in the dorsal part of the abdomen and are connected by vasa differentia with the penis.

Draw in the reproductive organs of your specimen on the outline already used for the digestive system.

Note the silvery trachial air sacs connected by tracheae in various parts of the body. Trace one of the trachea to a spiracle.

The nervous system can be dissected out by carefully removing the digestive and reproductive organs. Identify: the *supraoesophageal ganglion, suboesophageal ganglion,* the *thoracic ganglia,* and the *abdominal ganglia.*

Draw in the nervous system on the printed outline.



XXXIII

Grasshopper, Dorsal View of Nervous System

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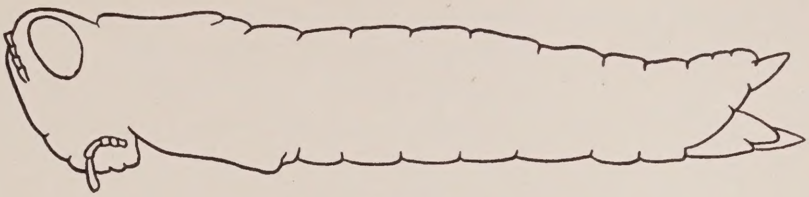
If a model of a lateral dissection of a grasshopper is available *draw* in from the model on the printed outline the structures shown.



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Grasshopper, Side View of Dissection

3. The Honey Bee

A. External Features of the Worker Bee. Note the division into *head, thorax,* and *abdomen.* In the head note the *compound eyes* and *antennae.* With a hand lens the *ocelli, mandibles,* and *proboscis* can be seen. The *fore wings* are attached to the *prothorax* and the *hind wings* to the *mesothorax.*

The *walking legs* are specially modified for collecting pollen and carrying it to the hive. Each leg consists of the following parts, *coxa, trochanter, femur, tibia, tarsus.*

a. With needles take off one of the prothoracic legs. Place it on a slide and separate the tibia and tarsus from the other segments. Examine the tibia and tarsus under the low power of the microscope. Note the *antenna cleaner* between the tibia and the large first segment of the tarsus and the *pollen brush* composed of long unbranched hairs attached to the first tarsal segment. The *eye brush* consists of short stiff hairs attached to the anterior edge of the inner surface of the tibia.

Draw the tibia and tarsus of the prothoracic leg.

b. In the same way take off one of the *mesothoracic* legs. On the large first tarsal note the *pollen brush,* similar to that on the prothoracic leg. On the inner edge of the tibia note the *wax pick.*

Draw the tibia and tarsus of the mesothoracic leg.

c. Do the same for one of the *metathoracic* legs. The *pollen basket* is on the outer side of the tibia and is formed by two fringes of long hairs, one on each edge which bend over and form with the surface a basket in which pollen is carried. On the first tarsal is the *pollen comb* composed of ten rows of sharp spines by which the pollen is transferred to the pollen basket. The distal end of the tibia and the proximal end of the first tarsal form between them the *wax pincers.*

Draw the tibia and tarsus of a metathoracic leg.

d. If available examine a queen bee and a drone.

QUESTION: Compare the queen and drone with the worker as to size, proportion of parts, and adaptations.

e. Adaptation. The legs of the worker bee illustrate in a remarkable way adaptation to a special activity.

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Question: Write a brief discussion of the adaptations of the legs of the worker bee, stating the function of each part and showing how it is adapted to perform that function.

B. The dissection and study of the internal anatomy of the bee is difficult and is best done under a binocular dissecting microscope. If attempted, the description in the text can be followed.

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XVI. ADDITIONAL INVERTEBRATES

1. A Sponge—Porifera

A. Examine a specimen of Grantia with a hand lens. Observe at one end the *osculum* or *excurrent opening* and at the opposite end the roughened area of *attachment* to the substratum. On the sides may be seen the minute *incurrent pores.*

Question: What kind of symmetry is represented in Grantia?

Draw in outline a single specimen showing the structures mentioned above.

B. With a razor blade or a sharp scalpel cut a longitudinal section passing through the osculum and the area of attachment or if available examine a prepared section. Observe with the hand lens or the low power of the microscope. Note the gastral cavity and the canals in the walls. These canals are of two kinds, *incurrent canals* which communicate with the outside through the incurrent pores already observed, and *excurrent canals* which open into the gastral cavity. Small openings connect the excurrent and incurrent canals.

Question: Trace the path taken by the water in passing through the sponge and indicate this path by arrows in your diagram on page 134.

Draw an outline of the entire longitudinal section.

Draw a diagram showing the canal system in the wall of the sponge.

2. A STARFISH—ECHINODERMATA

A. External Features. Note the *oral* and *aboral* surfaces, the *central disk* and the *arms*.

QUESTION: What kind of symmetry does the starfish possess?

At the center of the aboral surface note a small pore, the *anus*, and near it the *madreporite*, a porous plate connected with the water vascular system. The surface is covered with short *spines*, connected with calcareous plates or *ossicles*, which form the skeleton. These plates are covered by an ectodermal layer so that the skeleton is an *endoskeleton*. Look with a hand lens for the numerous minute pincers called *pedicellaria* and the finger-like *dermal branchiae*, respiratory organs.

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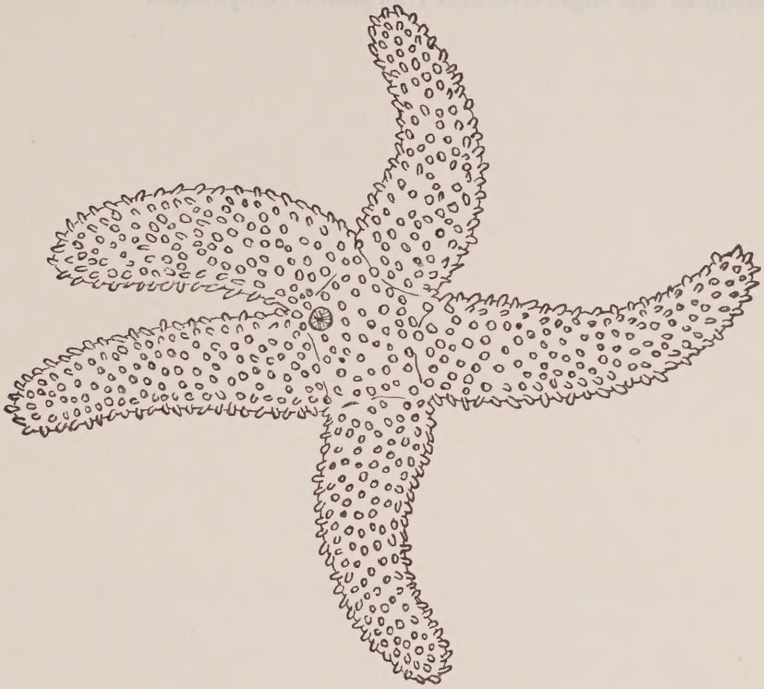
Label the printed outline.



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A Starfish, Dorsal View

Draw on a large scale a portion of the surface of the body showing pedicellaria; spines, ossicles, and dermal branchiae.

At the center of the oral surface may be seen the *mouth* surrounded by a membranous portion, the *peristome.* Extending from the mouth along each arm is an *ambulacral groove.* The ambulacral grooves lodge the *tube feet.* Observe the vacuum cups at the ends of the tube feet.

B. Internal Structure. Place the animal in a dissecting dish with the aboral surface uppermost and with a strong pair of scissors remove the endoskeleton from the aboral surface of the three arms farthest from the madreporite and from the adjacent part of the central disk, leaving the part containing the anus and the madreporite intact. Note the large *stomach* and the *pyloric caecae* extending from it into the arms. On either side of the pyloric caecae at the base of the arms are the *gonads*, ten in number. These open by ducts on the aboral surface between the arms.

Draw the dissection of the digestive and reproductive systems.

If the digestive and reproductive organs are removed the *water vascular system* may be seen as a *ring canal* surrounding the mouth and five *radial canals* passing one into each arm. From the radial canals short canals pass to the *tube feet.* Just before it joins a tube foot, each of these canals is enlarged to form an *ampulla.* A short vertical canal, called the *stone canal,* connects the ring canal with the madreporite. This rather complicated water vascular system is concerned with the movement of the tube feet.

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Draw the dissection of the water vascular system.

3. A Clam—Mollusca

A. External Features. Examine the shell. Note the two *valves* joined by a *ligament* which is on the dorsal side of the animal. On each valve *lines of growth* surround the *umbo.* In a living, undisturbed specimen in an aquarium the dorsal excurrent and the ventral incurrent siphons may be seen.

Question: What kind of symmetry is present in the clam?

Draw a lateral view of the animal showing the lines of growth and the umbo and label all structures seen.

B. Shell. Examine a broken piece of a clam shell and note the three layers which are, beginning at the inner side, the *mother-of-pearl layer*, which is the thin shiny layer, the *prismatic layer*, which makes up most of the shell, and the thin outer *organic layer*, which is frequently worn off.

Draw a section of the shell.

C. Internal Structure. Pry the two valves apart on the ventral side with a cold chisel or similar instrument. Insert the blade of a scalpel near the hinge and cut the adductor muscles. This will enable you to open the valves. Place the clam in a dissecting dish with its right side down and remove the left valve of the shell by cutting through the hinge and freeing it from the mantle of the left side. The soft parts may now be examined as they lie in the right shell. If the mantle has not been too much disturbed the arrangement of the posterior edges to form the *excurrent* and *incurrent siphons* can be recognized. Move aside the *mantle* and identify the plate-like *gills* which lie in the *mantle cavity*. There are two of them on each side. The dorsal portion of the shell is filled by the *visceral mass* which contains many of the organs and is continued ventrally into a more or less hard muscular mass, the *foot*. Just under the *anterior adductor muscle* which was cut in opening the shell is the *mouth*, between the members of a pair of flap-like *palps*. The digestive tract consists of a stomach and intestine and is imbedded in the soft tissues

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of the visceral mass and foot. On the dorsal side near the hinge the *heart* may be seen in the *pericardium.* On its way to the anus, which lies posterior to the *posterior adductor muscle,* the intestine passes through the pericardium and the heart. The *nephridia* are two dark colored organs lying just ventral to the pericardium. Careful dissection with needles is necessary to see the remaining organs. The *reproductive organs* are yellowish bodies imbedded in the visceral mass and the foot. The *nervous system* is represented by three *ganglia* connected by nerves, the *cerebro-pleural ganglion* ventral to the stomach and near the mouth, the *visceral ganglion* ventral to the posterior adductor muscle, and the *pedal ganglion* in the foot.

Draw the internal organs and label all parts.

D. Microscopic Examination of the Gills of a Fresh Clam. With scissors snip off a small portion of one of the gills and mount on a slide under a cover-glass in some of the fluid from the mantle cavity. Study the movement of the cilia.

QUESTION: Try to describe the movement of an individual cilium, and the movement of a group of cilia.

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XVII. THE ANATOMY AND PHYSIOLOGY OF THE FROG AND MAN

1. Observations on the Living Animal

a. Observe a frog in the resting position on the table.

Question: Is the frog a bilaterally symmetrical animal?

Identify the following; *dorsal*, *ventral*, *anterior*, *posterior*, *right*, *left*.

Question: Is there a distinct neck?

Identify *head* and *trunk*. On the head identify the *eyes*, *nostrils*, *mouth*, *eardrum* or *tympanum*, and dorsally between the eyes the small *brow spot*.

Question: Are the sense organs of the frog located in advantageous positions?

The eyes lie in the *orbits* which are supported by a bony skeleton which is a portion of the skull. In the center of the eye note the dark *pupil* through which the light passes into the eye, and surrounding the pupil a colored ring, the *iris*, which acts as a diaphragm controlling the amount of light entering the eye. There is an *upper* and a *lower* eyelid.

Question: With which eyelid does the frog cover its eye?

Question: Does the frog get the same or approximately the same picture with each eye?

Question: Is its vision stereoscopic?

Draw a side view of the frog's head twice natural size.

b. Compare the head of a frog with that of a man as regards general shape, position of the mouth, nostrils, eyes, and ears. Compare the eyes as to position in the orbit and direction of sight.

QUESTION: Are the eyes of man better protected against a blow than those of the frog?

QUESTION: Which eyelid covers the eye in man?

In man there is a vestige of a third eyelid called the *nictitating membrane*, which appears as a triangular mass of pink tissue in the inner angle of the eye. The nictitating membrane is highly developed in birds, where it is able to cover the whole eye. Identify the pupil and iris in the human eye.

QUESTION: When a person is said to have blue or brown eyes where is the color?

Compare what you can see of the human ear with what you can see of a frog's ear.

QUESTION: What structure has man which is entirely lacking in the frog?

QUESTION: Why is an external ear developed in mammals?

Compare the position of the nostrils in man and the frog.

QUESTION: Are the nostrils of man capable of closing like those of a frog?

QUESTION: Why is this not necessary in man? (See later under breathing.)

c. Attitudes.

QUESTION: In what position does the frog hold its front legs when resting on the ground?

QUESTION: Does the anterior portion of the trunk of the frog touch the ground?

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QUESTION: In what position are the toes of the hind legs?

Cause a frog to jump.

QUESTION: What is the action of the hind legs in jumping?

QUESTION: What part do the front legs play?

QUESTION: Is the frog in its usual resting position on land ready for a jump?

QUESTION: Of what advantage to the frog is this position?

Compare jumping in a frog and a man as to relative distances and method of jumping.

QUESTION: Why is a frog a better jumper than a man?

QUESTION: Can a frog run or walk?

d. Observe a frog floating in the resting position in an aquarium. Note the position of the fore and hind legs.

QUESTION: Are the sense organs advantageously located?

QUESTION: When floating does the frog see objects in the water or out of the water?

QUESTION: Does it hear sounds in the water or out of the water?

QUESTION: Can you see any advantage to the frog in being green on its dorsal side and white on its ventral side?

Cause a frog to dive from the resting position. Watch the movements of the head, forefeet, and hindfeet.

QUESTION: Was the frog in its resting position on the surface ready for a dive?

Watch a frog swimming in an aquarium. Compare its movements with those of a person swimming the breast stroke and with those of a fish.

QUESTION: Would you say that a frog is as well adapted for swimming as a fish?

Observe the breathing movements of a frog in the resting position out of the water.

QUESTION: Do the nostrils remain open?

QUESTION: Can you recognize any movement of the floor of the mouth?

QUESTION: What relation does this movement bear to the opening and closing of the nostrils?

QUESTION: When is air taken into the mouth from the atmosphere?

QUESTION: Can you notice any expanding or contracting of the sides of the animal corresponding to the breathing movements?

QUESTION: If air is forced from the mouth into the lungs when would you expect this to occur with reference to the movements you have observed?

QUESTION: *Write a description* of the breathing movements of the frog.

Watch a frog in the resting position on the bottom under water.

QUESTION: Do any of the breathing movements already observed occur under water?

Question: How can they be explained?

Compare the frog's breathing movements with your own.

Question: Do your nostrils open and close when you breathe?

Question: Does the floor of your mouth move?

Consciously go through the process of breathing and try to determine how air is inhaled and exhaled from the human lung. Distinguish between costal and diaphragmatic breathing.

2. The Skeleton

A. Cartilage and Bone.

a. Examine a piece of fresh or preserved cartilage with the naked eye.

Question: Is cartilage flexible?

b. Examine a prepared slide containing a section of *cartilage.* Note the transparent *matrix* and the *lacunae* in which are the *cartilage cells.* Note the *nuclei* in the cartilage cells.

Question: What evidence do you find of the growth and division of the cartilage cells?

Draw a portion of the section.

c. Examine a cross-section of a long bone as seen with the naked eye and identify the *marrow cavity.*

Draw the section.

d. Examine the femur which has been cut in two longitudinally.

Question: What do you recognize regarding the arrangement of the bony material at the ends?

e. Examine a prepared slide of *bone.* This will be a ground section of dried bone. Note the relatively opaque *matrix* which is composed chiefly of calcium carbonate and calcium phosphate. The *lacunae* or cell spaces are arranged concentrically around the *marrow cavity* or around the canals in which blood vessels and nerves pass. Note also the fine *canaliculae* which connect the lacunae. The bone cells will not be seen as they are dried up by the method of preparation.

Draw a portion of the section showing the structures mentioned.

B. General Features of the Skeleton. Compare the general features of the skeleton of a frog with that of a man, noting the correspondence in structure in the skull, vertebral column, girdles, and limbs.

Question: What are the most striking points of difference?

C. The Skull.

a. The Frog's Skull. Note the small elongated, box-like *cranium* occupying the central dorsal portion of the skull, the large U-shaped upper *jaws* attached to the cranium by the *nasal capsules,* the bones surrounding the *orbit,* and the *auditory capsules.* At the posterior end of the cranium is a large opening, the *foramen magnum,* through which the brain becomes continous with the

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spinal cord. Ventral to the foramen magnum is a pair of rounded projections, the *occipital condyles.*

b. The Human Skull. In a human skull identify the large *cranium*, the *orbits*, the small *nasal bones*, the *cheek bone*, the upper jaw or *maxilla* and the lower jaw or *mandible.* The *auditory capsule* is included in the *temporal bone*, on the under side of which is the *external canal of the ear* at the inner end of which in life is the eardrum. Posterior to the external canal of the ear is the *mastoid bone.* The *foramen magnum* is in the center of the under side of the skull and has an *occipital condyle* on either side of it.

c. Comparison of Skulls of Frog and Man. Fill in the table.

	FROG	MAN
Relative size of cranium		
Position of nasal cavity		
Position and relative size of orbits		
Position and relative size of auditory capsules		
Position of foramen magnum		
Occipital condyles, number and position		
Relative size of jaw		

D. The Vertebral Column.

a. Examine a lumbar vertebra and identify, the *centrum, neural arch, neural spine, neural canal, transverse processes*, and *articular surfaces.*

Draw a front view of a lumbar vertebra.

b. Vertebral Column of Man. Fill in the table.

VERTEBRAE	NO.	NEURAL PROCESS	TRANSVERSE PROCESS	ARTICULATION FOR RIBS	OTHER PECULIARITIES
Atlas					
Axis					
Remaining cervical					
Thoracic					
Lumbar					
Sacral					
Coccygeal					

c. Examine the vertebral column of a frog.

QUESTION: How many different kinds of vertebrae are there in the frog? Name each kind.

E. Ribs of Man. Fill in the table.

	ARTICULATION OF DORSAL END	ATTACHMENT OR ARTICULATION OF VENTRAL END
1st rib		
3rd rib		
8th rib		
12th rib		

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F. Pectoral and Pelvic Girdle of Frog. Fill in the names of the bones in the following table:

	PECTORAL GIRDLE	PELVIC GIRDLE
Dorsal bone		
Anterior bone		
Posterior bone		
Articulation for limb		
Articulation with vertebral column		

G. Pectoral and Pelvic Girdle of Man. Fill in the names of the bones in the following table:

	PECTORAL GIRDLE	PELVIC GIRDLE
Posterior bone corresponding to dorsal bone in frog		
Anterior and superior bone, corresponding to ventral and anterior in frog		
Anterior and inferior bone corresponding to ventral and posterior bone in frog		
Articulation for limb		
Articulation with vertebral column		

H. The Fore Limbs of Man and of the Frog. Fill in the table.

PARTS	NUMBERS AND NAMES OF CORRESPONDING (HOMOLOGOUS) BONES			
	Man		Frog	
	Number of Bones	Names	Number of Bones	Names
Upper arm				
Fore arm				
Wrist				
Palm				
Fingers				

I. The Hind Limbs of Man and of the Frog. Fill in the table.

PARTS	NUMBERS AND NAMES OF CORRESPONDING (HOMOLOGOUS) BONES			
	Man		Frog	
	Number of Bones	Names	Number of Bones	Names
Thigh				
Shank				
Ankle				
Arch				
Toes				

J. Examine carefully each of the bones in the set provided and learn the name and position in the skeleton of each of the separate bones.

3. THE MOUTH CAVITY

A. Frog.

NOTE. Two frogs will be required for the study of the internal organs. The study of the mouth cavity and the digestive system should be made on a freshly killed frog which will then be preserved as frog number 1. This frog will later be used for the study of the respiratory, excretory, and reproductive systems. A second freshly killed frog, frog number 2, will be used for the study of the heart and circulation, including the injection of the arteries. The student should then return to frog number 1 for the nervous system, sense organs, muscles, and joints.

In a freshly killed or preserved frog extend the slit-like mouth opening by cutting through the angles of the jaws with the scissors. Place the frog with its dorsal side down in the dissecting dish. Pin out the fore and hind legs and pin back the lower jaw so as to expose the mouth cavity. Examine the upper and lower jaws and the roof of the mouth for *teeth.* The teeth are small, and to be properly seen require a hand lens. They can be felt with the tip of the finger or a scalpel.

Question: Are there teeth on both upper and lower jaws?

The teeth on the roof of the mouth are called *vomerine teeth.*

Identify the *tongue.*

Question: How is it attached?

Question: How may it be protruded?

Pass hog bristles into each of the nostrils or external nares, already identified in the study of the external features, and observe their emergence into the mouth cavity by the internal nares.

In the floor of the mouth posterior to the tongue note a longitudinal slit-like opening, the *glottis.* The cartilagenous voice box or *larynx* can be felt by placing the tip of the finger on the glottis. Air passes from the mouth through the glottis into the larynx. Posterior to the glottis at the extreme posterior end of the mouth cavity is the opening into the *oesophagus.* This opening, unlike the glottis, is surrounded by soft tissue and is distensible allowing the handle of a dissecting needle to enter easily.

Question: Account for the structural differences between the glottis and the opening into the oesophagus by considering their differences in function.

In the male frog in the floor of the mouth near the angles of the jaws can be seen the openings into the *vocal sacs.*

Draw the mouth cavity of the frog.

B. The Mouth Cavity of Man. This exercise may be carried out by the student at home. There will be required a small mirror, a spoon, and a flash-light. Place the mirror in such a position as to give a good view of the open mouth.

Identify the cavity bounded externally by the lips and cheeks and internally by the teeth and gums, which is called the *vestibule of the mouth.* Determine the extent of this cavity by inserting the finger between the lips and teeth and following around the outer edge of the upper and lower jaws. Identify the *teeth* in the lower jaw as follows; in front four *incisors* (two on either side of the median line) flattened and especially adapted for cutting food; lateral to these one *canine* on each side more conical in shape and often projecting slightly beyond the incisors; next lateral and posterior to the canines two *premolars* and three *molars* on each side adapted for grinding food, the last molar also called the *wisdom tooth* is very variable in its development and sometimes absent. The same series of teeth with certain minor differences in position and structure is found in the upper jaw. Identify them.

QUESTION: How many teeth are there in each jaw?

QUESTION: Compare the teeth of the frog with those of man.

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QUESTION: What can you surmise from the teeth regarding the food of each?

The *roof of the mouth* is occupied by the *palate.* Determine the extent of the hard palate by feeling with the finger. The hard palate is continuous with the *soft palate.* The hard palate is hard because it is supported by bone. Hold the flash-light below the level of your mouth and direct the light onto the roof of the mouth. Notice that the soft palate ends in a pointed projection the *uvula*, which hangs down into the cavity. On either side of the uvula and connected with it are folds of muscular tissue. These folds are called the *pillars of the fauces.* The two anterior folds which extend on either side from the uvula to the base of the tongue are called the *anterior pillars of the fauces.* The opening in the back of the mouth which they bound is called the *fauces.* Through this opening the mouth becomes continuous with the pharynx. The pharynx is the cavity through which the air from the nostrils or mouth passes in going to and from the lungs. In man it is divided into a *naso-pharynx* and an *oro-pharynx.* Only the oro-pharynx is visible directly from the mouth cavity. The naso-pharynx lies above the palate and behind the nose. The posterior pillars of the fauces lie in the oro-pharynx and connect the soft palate with the side of the pharynx.

Open the mouth wide and press the back of the tongue down and forward with the handle of a spoon or other conveniently shaped instrument. On each side of the oro-pharynx, between the anterior and posterior pillars of the fauces is a *tonsil.* Normally a tonsil appears as a compact reddish body surrounded by a groove. The *adenoids*, which like the tonsils are lymph glands, are situated above the latter in the naso-pharynx and cannot be seen directly from the mouth cavity. It is difficult to see the *epiglottis* directly from the mouth cavity, it lies beyond the back of the tongue and in the act of swallowing closes the *glottis*, the opening into the larynx. The pharynx leads into the oesophagus, the opening into which lies posterior to the glottis, and is not visible directly from the mouth cavity.

C. Study a model or chart of a sagittal section of the human head. Trace out the different systems. Identify the following structures on the model or chart and ***label*** them on the printed diagram on page 154:

Skeleton: Cranium, Vertebral column, Upper jaw, Lower jaw.

Digestive system: Lips, Gums, Teeth, Mouth cavity, Hard palate, Soft palate, Tongue, Tonsils, Oesophagus.

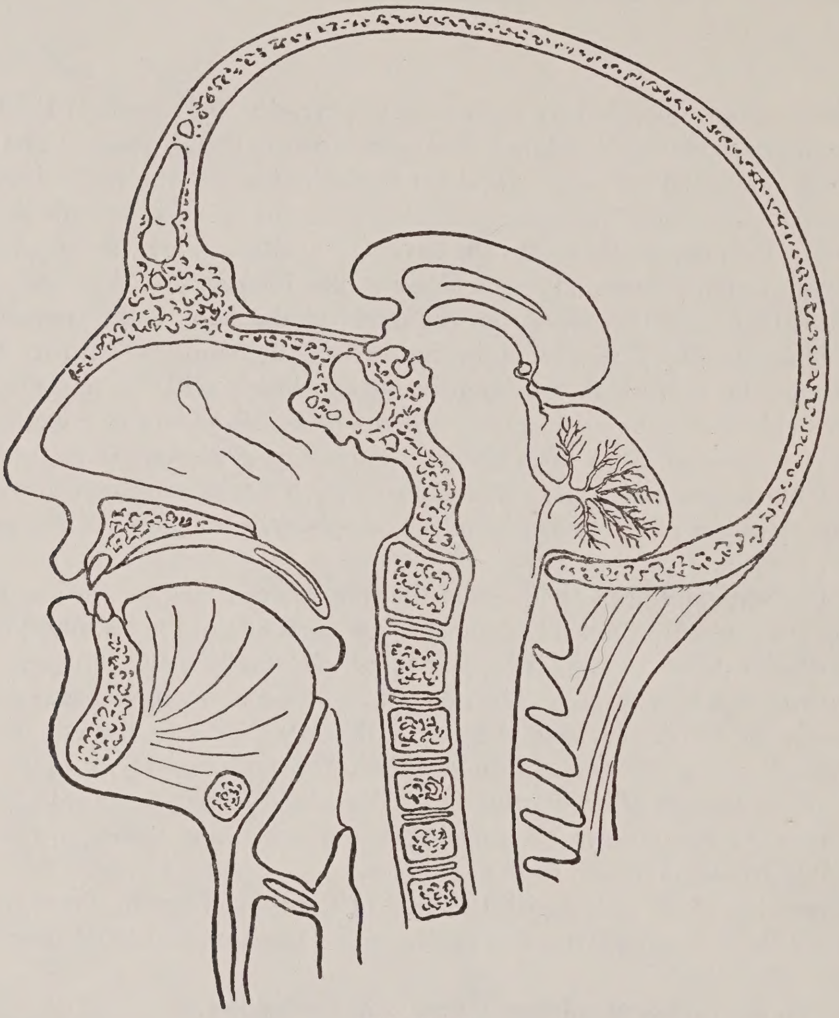
Respiratory system: Nostril (show position by arrow), Nasal cavity, Naso-pharynx, Frontal sinus, Sphenoidal sinus, Oro-pharynx, Epiglottis, Glottis, Larynx, Vocal cords, Trachia.

Nervous system: Cerebral hemispheres, Cerebellum, Spinal cord.

Draw in and label on the printed diagram any other important structures seen in the model or chart.

QUESTION: Trace the path taken by the air in respiration and the path taken by the food in eating and swallowing.

Label the structures on the printed drawing.



XXXVI
Human Head, Sagittal View

4. Digestive System

A. Digestive System of Frog.

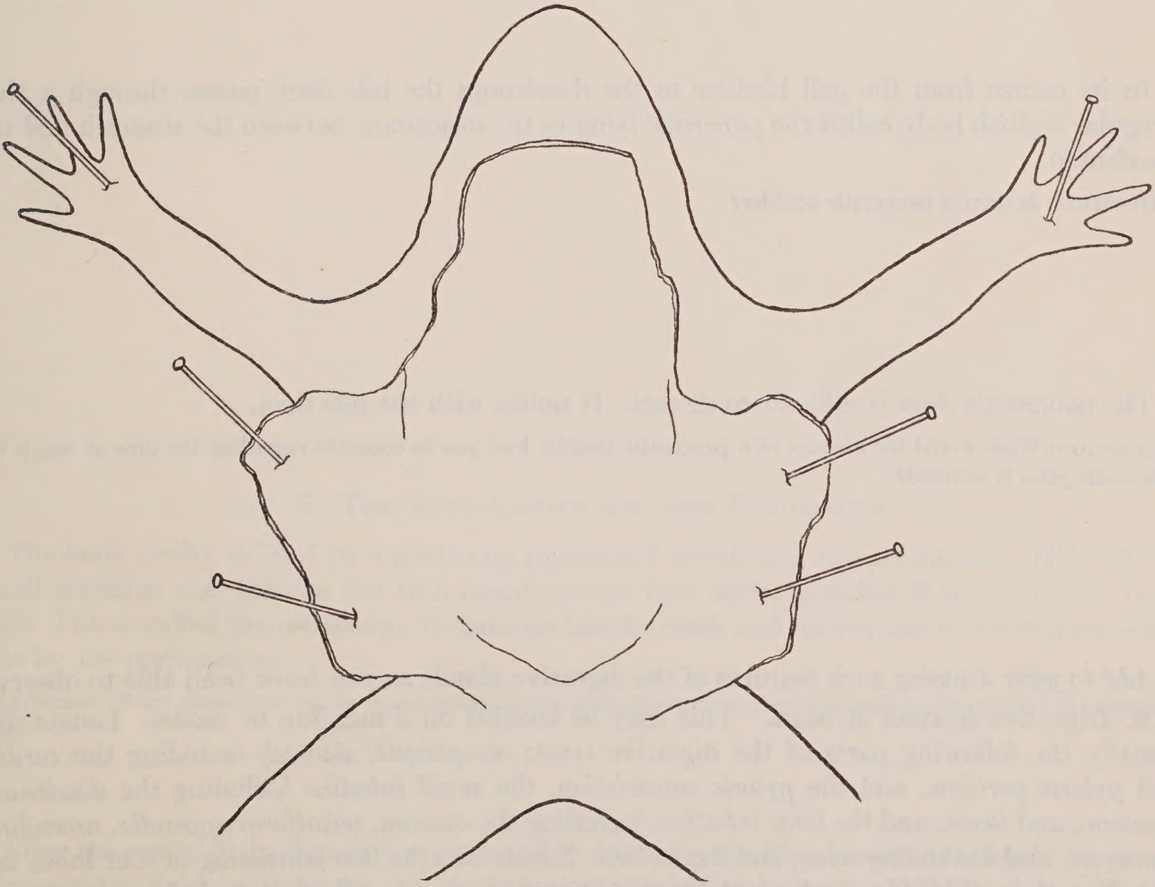
a. Digestive Tract. With scissors carefully cut through the ventral body wall to one side of the median line from the posterior end of the animal until you encounter the bony structure (pectoral girdle) between the forelegs. At either end of this cut, cut laterally so as to be able to pin back two folds and expose the abdominal cavity.

Question: In opening the body cavity of the frog did you cut through any ribs?

If the animal is a female the body cavity may be almost filled by two irregular masses, consisting almost entirely of small dark spherical bodies. These masses are the ovaries and the small dark spheres are eggs. In this case remove most of the ovaries, noting, however, where they are attached to the body wall. The oviducts may also be much enlarged in the female during the breeding season. They then appear as large irregular coiled white tubes. If this is the case one of them should be removed, leaving the other entire for subsequent study.

b. Insert the handle of a dissecting needle or a probe through the mouth into the oesophagus as far as it will go. Feel in the body cavity for the end of this probe. This will enable you to identify the anterior end of the *stomach*, into which the oesophagus leads. Determine the extent and shape of the stomach. The constriction at its posterior end is called the *pyloric constriction.* The stomach is followed by the *small intestine.* The first part of the small intestine, which is about equal in length to the stomach, runs anteriorly and is called the *duodenum.* The latter part of the small intestine which is called the *ileum* is much coiled and of considerable extent. The small intestine leads into the large intestine, the first part of which is the *rectum.* The rectum is a thin-walled tube about the same size as the stomach at the posterior end of the body cavity. In a ventral view such as is presented by your dissection it is somewhat hidden by the *urinary bladder*, a thin walled bilobed sac which differs much in appearance according to the amount of urine which it contains. In the frog the rectum does not open directly to the exterior as in mammals. Instead it opens into a short tube called the *cloaca* (Latin, sewer) into which the excretory and reproductive organs also open. In your dissection the cloaca is largely hidden by the muscles of the legs and posterior part of the trunk. The opening of the cloaca to the exterior is called the *anus.* Insert a probe into the anus, which will be found between the hind legs, and feel for it in the rectum.

Draw the digestive tract on a printed outline of the frog.



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Frog, Dissection of Digestive Organs

c. Digestive Glands. Surrounding the anterior portion of the stomach on its ventral and lateral sides are the dark brown *lobes of the liver.*

QUESTION: How many lobes are there?

Partly imbedded in the median lobe of the liver is the green *gall bladder*, green because of the color of the contained *gall* or *bile.* In the freshly killed frog the *bile duct*, running from the gall bladder to the duodenum, can usually be easily recognized by its green color.

QUESTION: What is the function of the ball bladder?

QUESTION: Where would you expect the bile to exercise its digestive function?

In its course from the gall bladder to the duodenum the bile duct passes through a thin irregular whitish body called the *pancreas*, lying in the membrane between the stomach and the duodenum.

QUESTION: Is there a pancreatic bladder?

The pancreatic duct is difficult to dissect. It unites with the bile duct.

QUESTION: What would the absence of a pancreatic bladder lead you to conclude regarding the time at which the pancreatic juice is secreted?

Add to your drawing such features of the digestive glands as you have been able to observe.

B. Digestive System of Man. This may be studied on a manikin or model. Locate and identify the following parts of the digestive tract; *oesophagus*, *stomach* including the *cardiac* and *pyloric portions*, and the *pyloric constriction*, the *small intestine* including the *duodenum*, *jegunum*, and *ileum*, and the *large intestine*, including the *caecum*, *vermiform appendix*, *ascending*, *transverse*, and *descending colon*, and the *rectum.* Locate also the *liver* consisting of four lobes and including the *gall bladder*, *cystic duct*, *hepatic ducts*, and *common bile duct*, and the *pancreas* and the *pancreatic duct.*

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Draw **in outline the digestive tract of man with the parts spread out and showing their relative lengths.**

5. The Body Cavity and the Peritoneum

The body cavity is lined by a glistening pigmented membrane, the *peritoneum.* Hold up the small intestine and observe the thin membraneous fold which attaches it to the dorsal body wall. This is called the *mesentery.* It contains blood vessels and nerves and is covered on either side by the peritoneum.

Question: What structures can be seen running in the mesenteries from the body wall to the parts of the digestive tube?

After the study of the digestive system and body cavity the frog (number 1) should be placed in preserving fluid and kept for the dissection of the respiratory system. Before doing this the lungs and bladder should be inflated by blowing with a blow pipe into the glottis and anus respectively.

6. The Respiratory System

A. The dissection of the respiratory system should be carried out on the frog preserved at the end of the previous exercise. With the scissors cut through the pectoral girdle on either side about half way between the median line and the shoulder joint, and dissect away the middle portion, laying bare the heart. The heart will be studied in another frog and can be removed from this one so as to expose the larynx which lies dorsal to it. The larynx is a cartilagenous box-like structure communicating on the one hand with the mouth cavity through the glottis and on the other hand separately with each of the two lungs. Open the larynx by a longitudinal slit. Insert a bristle into the glottis and verify that it leads into the larynx. Observe the openings of the lungs into the larynx. Cut open one of the lungs and with a hand lens observe that the cavity is divided up by partitions extending from the walls, giving to it the appearance of a honeycomb.

Question: How does this structure increase the efficiency of the lungs?

Observe two folds extending longitudinally in the larynx. These are the *vocal cords*. Sound is produced by the vibrations of the edges of these folds when air is forced between them.

Draw a cross-section of a lung ten times natural size.

B. The Human Respiratory System. The human *larynx* or voice box forms the prominence in front of the neck called the "Adam's apple." The position of the lungs in the two *pleural cavities* separated from the abdominal cavity by the *diaphragm* should be determined in a manikin or on a chart. The vibrations of the *vocal cords* can be felt by placing the fingers on the "Adam's apple" and saying "A-a" or any other vowel sound. In whispering the vocal cords do not vibrate.

Question: How is the sound made in whispering?

Question: Compare the respiratory movements of a frog and a man.

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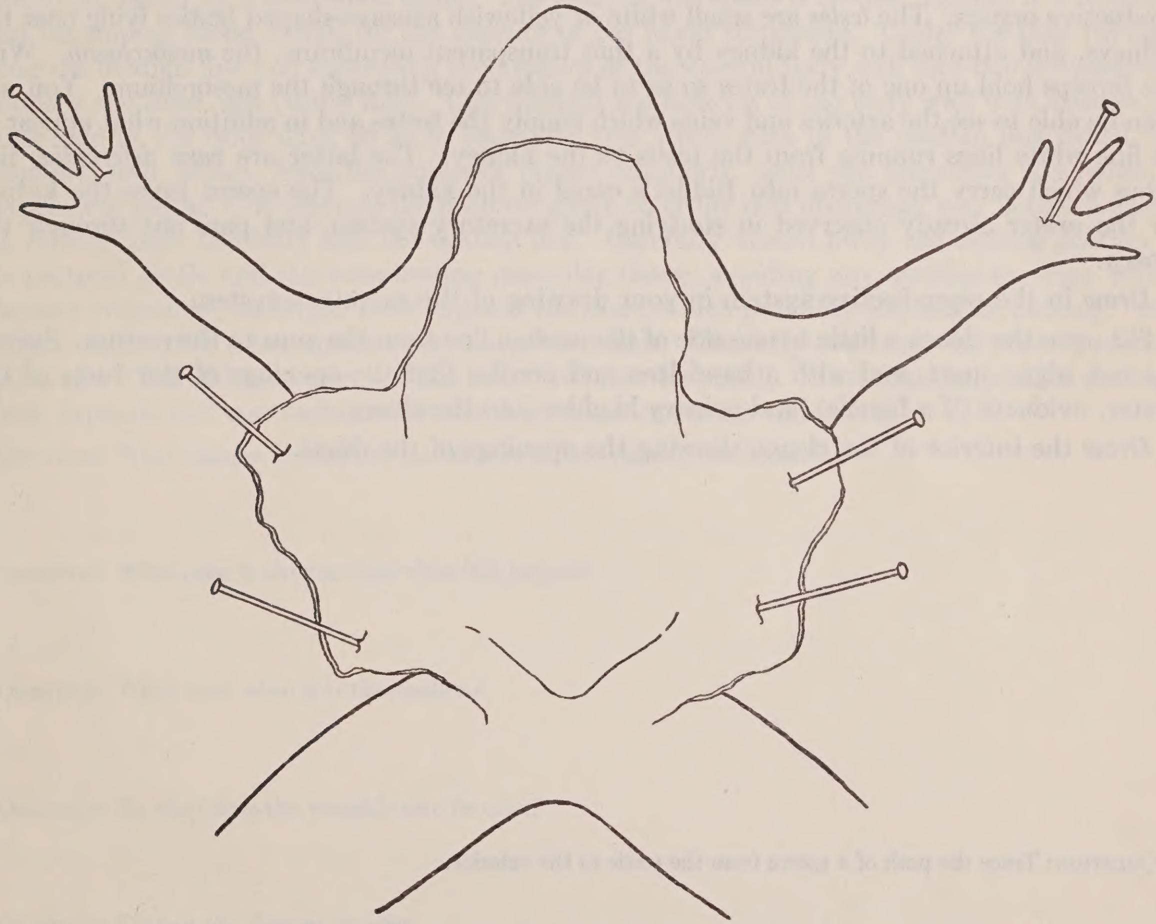
7. THE EXCRETORY SYSTEM

A. The kidneys of the frog are paired reddish flat oval-shaped bodies lying against the dorsal body wall. From the outer edge of each a duct, the *ureter*, can be traced to the cloaca. On the ventral side of the cloaca and communicating with it is a bilobed sac, the *urinary bladder*. Running along the ventral surface of each kidney is a streak of yellow. This is the *adrenal body*, one of the ductless glands. Attached to the anterior end of each kidney is an irregularly lobed *fat body*, also yellowish. Neither the adrenal body nor the fat body have anything directly to do with the function of excretion.

Draw the excretory system in a prepared outline of the frog.



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FROG, DISSECTION OF EXCRETORY AND REPRODUCTIVE SYSTEMS

B. Study the human *excretory system* on a model or a chart. Note the shape and position of the *kidneys* and identify the *hilus*, *ureter*, *urinary bladder*, and *urethra*. In a model or diagram of a longitudinal section of a human kidney locate, *pelvis of kidney*, *cortical substance*, *medullary substance*, *malpighian bodies*, *uriniferous tubules*, and *papillae*.

Question: Trace the path of the urine from a malpighian body to the exterior.

8. The Reproductive System

The reproductive system is closely connected, structurally, with the excretory system. If your frog is a female you have already recognized the *ovaries* and the *oviducts*. Trace the oviducts anteriorly and find their funnel-shaped *openings into the body cavity*. Trace them posteriorly and find their openings into the cloaca. Obtain a male frog for the study of the male reproductive organs. The *testes* are small white or yellowish sausage-shaped bodies lying near the kidneys, and attached to the kidney by a thin transparent membrane, the *mesorchium*. With the forceps hold up one of the testes so as to be able to see through the mesorchium. You will then be able to see the arteries and veins which supply the testes and in addition what appear to be fine white lines running from the testis to the kidney. The latter are *vasa deferentia*, fine tubes which carry the sperm into Bidder's canal in the kidney. The sperm leave the kidney by the ureter already observed in studying the excretory system, and pass out through the cloaca.

Draw in the reproductive system in your drawing of the excretory system.

Slit open the cloaca a little to one side of the median line from the anus to the rectum. Spread the cut edges apart, and with a hand lens and needles find the openings of the ducts of the ureter, oviducts (if a female), and urinary bladder into the cloaca.

Draw the interior of the cloaca showing the openings of the ducts.

Question: Trace the path of a sperm from the testis to the exterior.

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QUESTION: Trace the path of an egg from the ovary to the exterior.

9. THE CIRCULATORY SYSTEM

A. The Heart of the Frog. The dissection of the heart and the circulatory system will be carried out on a second freshly killed frog (number 2). As before pin the frog out in the dissecting tray ventral side up. With the scissors cut through the skin only along the median line from anterior to posterior. Note that the skin lies loosely on the body and is separated from the underlying tissue by a fluid-filled space. The fluid in this space is *lymph.* Lymph is a colorless fluid resembling blood except for the absence of red blood corpuscles. Under the skin running along the median line and separating the muscles of the ventral body wall into two symmetrical groups is the *linea alba* (white line). Cut through the muscles of the body wall with scissors on either side of the linea alba, so as to leave the vein which runs in the median line called the *abdominal vein*, intact, from the posterior region anteriorly, until you encounter the bones of the pectoral girdle. Cut through the pectoral girdle on either side about half way between where the foreleg joins the body and the median line. Carefully dissect away the median portion of the pectoral girdle and the surrounding muscular tissue, avoiding any arteries or veins which you may encounter, until you have exposed the *heart*, which probably will still be beating. The heart is enclosed in a transparent sac, the *pericardium.* Carefully cut away the ventral portion of this sac. The different parts of the heart will now be visible. Note first the pinkish *ventricle* which expands and contracts and at the same time moves up and down.

QUESTION: What changes in color can you observe in the ventricle as it contracts?

QUESTION: What color is the ventricle when it is largest?

QUESTION: What color when it is the smallest?

QUESTION: To what does the ventricle owe its color?

QUESTION: Explain the changes in color.

Anterior to the ventricle are the two *auricles*, which are much darker in color.

QUESTION: Do they contract?

QUESTION: What is the relation between the time of contraction of the auricles and the time of contraction of the ventricle?

QUESTION: What evidence have you that the blood passes from the auricles to the ventricle?

Lift up the ventricle and note the dark thin walled *sinus venosus.*

QUESTION: With which of the auricles is it connected?

The blood from the body enters the sinus venosus by three large veins, one posterior, the *postcaval,* and two anterior, one on either side, the *precaval veins.* Only the junction of the postcaval vein with the sinus venosus can be seen at this stage of the dissection. Anterior to the ventricle and extending from it ventral to the auricles is the *conus arteriosus.* The posterior part of this tube is slightly thicker than the anterior part and is called the *bulbus cordis.* The anterior part is the *truncus arteriosus.* The truncus arteriosus divides into two lateral divisions at about the level of the anterior end of the auricles. Each of these trunks immediately gives rise to three arteries, which are named from posterior to anterior, *pulmo-cutaneous, aorta,* and *common carotid.*

QUESTION: Can you see any change in the bulbus cordis corresponding to the contractions of the ventricle?

QUESTION: Does blood pass from the ventricle into the bulbus cordis?

The student will have already noted that the right auricle receives blood from the sinus venosus. The left auricle receives blood from the lungs. The blood from both auricles passes into the ventricle at the same time.

QUESTION: Write a description of the course of the blood through the heart.

Draw a ventral view of the heart on the printed outline of the frog labeled " dissection of arteries" (XL).

B. The Human Heart. Examine a model or a chart showing the structure of the human heart. Identify the *right* and *left ventricles, right* and *left auricles,* the *aorta, pulmonary arteries, superior* and *inferior venae cavae.*

QUESTION: With which ventricle is the aorta connected?

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Question: With which ventricle are the pulmonary arteries connected?

Question: With which auricle are the superior and inferior venae cavae connected?

Question: With which auricle are the pulmonary veins connected?

Open the model or examine the part of the chart showing the interior of the heart. Determine the connections between the auricles and ventricles. Between the left auricle and the left ventricle is the *bicuspid valve*, and between the right auricle and the right ventricle is the *tricuspid valve.*

Question: Why are the bicuspid and the tricuspid valves so named?

Study the structure of the bicuspid valve. Identify the flaps of the valve, the *trabeculae carneae*, and the *chordae tendineae.*

Question: Briefly describe the action of the tricuspid and bicuspid valves.

Observe the *semilunar* valves in the aorta.

Question: What is their action?

Identify the *pulmonary arteries.*

Question: Trace the blood through the right side of the heart.

QUESTION: Trace the blood through the left side of the heart.

C. Arteries and Veins of the Frog. After you have completed the study of the living heart of the frog a coloring solution should be injected through the ventricle into the bulbus cordis. This will pass out into the arteries and make them more easily seen. Obtain the assistance of your instructor in making the injection.

a. Veins. It is best to make the dissection of the veins before the arteries since the former are not colored by the injection and are therefore likely to be torn away while the student is looking for the arteries. Remove the skin from the legs. Look on the lateral side of the thigh for a vein which looks like a dark cord extending from between the muscles of the dorsal region of the thigh to the lateral body wall. This is the *sciatic vein.* Trace this vein down the leg as far as possible. Then trace it back toward the trunk and find that it passes into the abdominal cavity and joins the *renal portal vein,* which runs to the kidney and along its lateral edge. Trace the renal portal vein posterior to its junction with the sciatic vein (this part of the renal portal vein is sometimes called the external iliac vein) and find that the renal portal vein is continued into a vein, the *femoral vein,* which passes down the leg and brings blood from the ventral portion of the thigh and the lower portion of the leg and gives off a branch towards the median line, the *pelvic vein.* The pelvic vein of one side unites with its fellow of the other side to form the *abdominal vein,* which will be traced later. Trace the femoral vein out into the muscles of the leg and foot.

Move aside the viscera in the anterior portion of the body cavity so as to be able to see the large vein which passes into the liver. This is the *posterior vena cava.* It passes through the liver to the sinus venosus. Trace the posterior vena cava posteriorly between the kidneys clearing away the membranes and determine where it originates.

Note the veins from the stomach and intestines which join to form a vein, the *hepatic portal,* which goes through the pancreas to enter the liver.

QUESTION: What two paths are open to blood returning to the heart from a hind leg? Trace a blood corpuscle through each of the paths.

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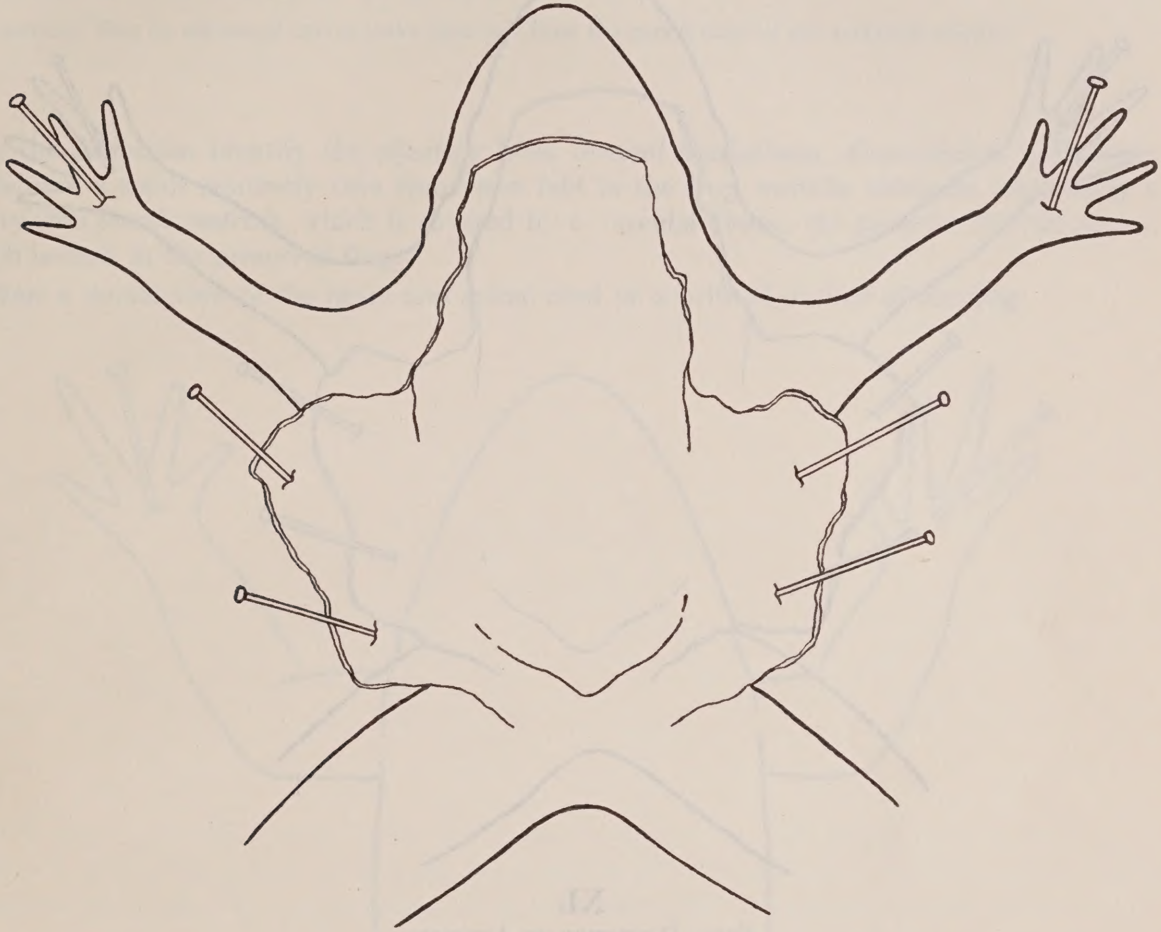
Draw on a printed outline of the frog such of the veins as you have been able to observe.



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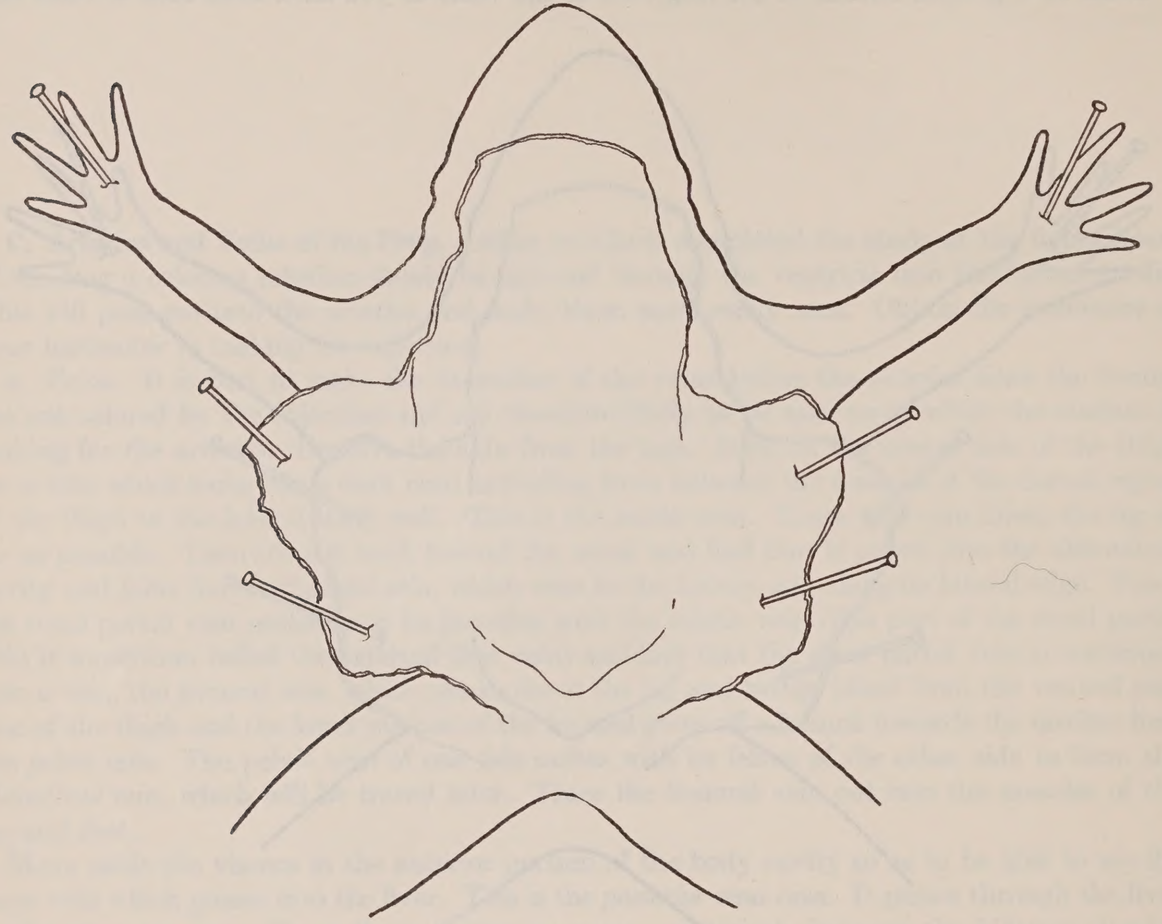
Frog, Dissection of Veins

b. Arteries. Begin the dissection of the arteries by tracing the arteries leaving the truncus arteriosus. Start with the *common carotid.* This divides into an *external carotid* or *lingual* artery which goes to the lower jaw, and an *internal carotid* which goes to the dorsal side of the head. At its origin the internal carotid artery is dilated to form the *carotid gland.* It often happens that the injecting fluid does not go beyond the carotid gland. Follow next the *pulmocutaneous artery.* This divides into a *cutaneous artery* to the skin and *pulmonary artery* to the lung. Now follow the *systemic arch* which bends round the oesophagus to join its fellow of the opposite side and form the *dorsal aorta.* On its way the aortic arch gives off an artery, the *subclavian artery,* which should be traced to the foreleg. Trace the dorsal aorta as it passes posteriorly along the dorsal body wall. Near its beginning it gives off the *coeliac-mesenteric* which gives branches to the liver, *hepatic;* to the stomach, the *gastric;* and to the intestine, the *anterior mesenteric.* Further on the dorsal aorta gives off the *urinogenital arteries* to the kidney and ovaries or testes as the case may be. Posteriorly the dorsal aorta divides into two *iliac arteries* which supply the legs. Each iliac artery gives off a *femoral artery* to the anterior part of the thigh and continues as a *sciatic artery* supplying the remainder of the hind leg.

Draw in on the printed outline such arteries as you have been able to observe.



XL

Frog, Dissection of Arteries

D. Arteries and Veins of Man.

a. Arteries. Study a chart showing the human arterial system. Identify the following arteries which branch off from the aorta: *innominate,* left *common carotid,* left *subclavian, coeliac, superior mesenteric, inferior mesenteric, common iliac.*

b. The aortic arch in the adult man corresponds to the fourth aortic arch in the embryo and the left systemic arch in the adult frog.

Question: On which side is the single aortic arch in man?

c. Veins. Study a chart showing the venous system and identify the main veins.

10. The Nervous System

A. The Brain and Spinal Cord of the Frog. For the dissection of the nervous system and sense organs, preserved frog number 1 should be used. With a scalpel carefully dissect away the dorsal portion of the cranium. Hold the scalpel horizontally and avoid digging the point into the soft nervous tissue which lies immediately beneath the bone. Having exposed the brain in

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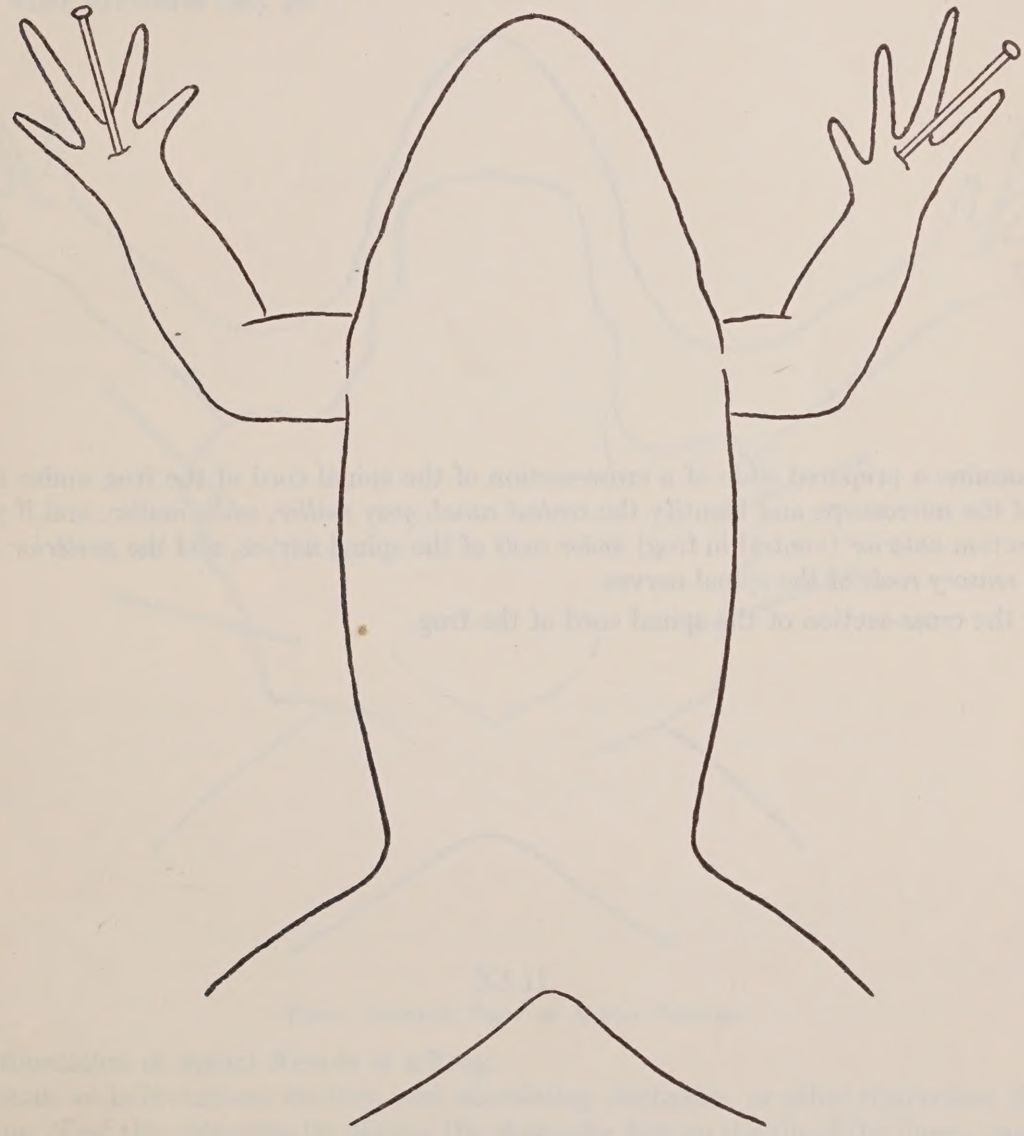
this way, cut, with the scissors, through the neural arches of the vertebrae on each side of the neural spines. This will expose the spinal cord.

QUESTION: How do the spinal nerves make their exit from the neural canal of the vertebral column?

In the dissection identify the *olfactory lobes*, *cerebral hemispheres*, *diencephalon*, *optic lobes*, *cerebellum*, a small relatively thin transverse fold in the frog, *medulla oblongata*, containing a cavity, the *fourth ventricle*, which is covered by a vascular tissue, the *posterior choroid plexus*, which is dark in the preserved frog.

Draw a dorsal view of the brain and spinal cord on a printed outline of the frog.



XLI

FROG, DISSECTION OF BRAIN AND SPINAL CORD

The nerves leading from the brain and spinal cord may now be cut and the entire central nervous system removed to a watch glass where it may be studied in a ventral view. Identify those of the structures already seen in dorsal view which appear in a ventral view. In addition identify the *optic chiasma*, *infundibulum*, and *pituitary body*, the latter a ductless gland.

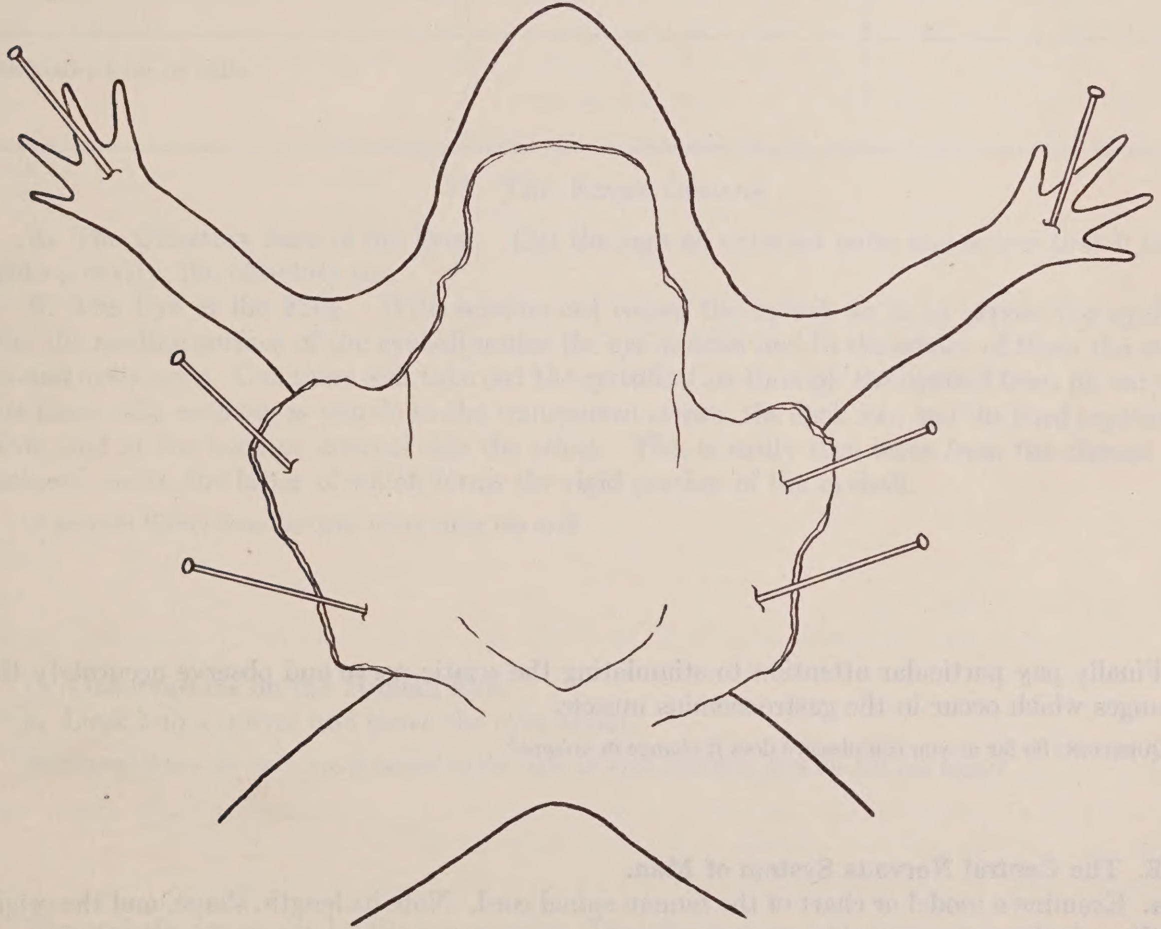
Draw a ventral view of the brain and spinal cord on the same scale as the dorsal view.

B. Examine a prepared slide of a cross-section of the spinal cord of the frog under the low power of the microscope and identify the *central canal*, *gray matter*, *white matter*, and if present in the section *anterior* (ventral in frog) *motor roots* of the spinal nerves, and the *posterior* (dorsal in frog) *sensory roots* of the spinal nerves.

Draw the cross-section of the spinal cord of the frog.

C. The Peripheral Nervous System of the Frog. Pin the frog out in the dissecting dish ventral side uppermost. Remove the viscera and note the spinal nerves. Continue the dissection anteriorly as far as the base of the skull. The second spinal nerve may be easily recognized as the largest of the anterior nerves—trace it to the foreleg. Next identify spinal nerves numbers I to IX. The tenth spinal nerve is small and not so easily seen. Note that the spinal nerves numbers VII, VIII, and IX are joined by branches forming the *sciatic plexus.* The *sciatic nerve* arises from spinal nerves VIII and IX. Trace the sciatic nerve through the body wall and into the hind leg. Note that it branches in the middle of the thigh into an anterior portion, the *peroneal nerve,* and a posterior portion, the *tibial nerve.* Trace the tibial nerve to its ramifications in the gastrocnemius muscle and the muscles of the toes of the hind feet.

Draw on a printed outline the spinal nerves you have been able to see, label them and indicate to what structures they go.



XLII

Frog, Ventral View of Spinal Nerves

D. Stimulation of Spinal Nerves of a Frog.

a. Obtain an inductorium, battery, and stimulating electrodes, or other convenient shocking apparatus. Test the apparatus by placing the electrodes first on the tip of the finger, previously moistened, and then on the tongue. Too strong a current through the electrodes will kill the nerves of the frog.

b. To Pith a Frog. Hold the frog in the left hand, dorsal side uppermost. With the index finger on the head and the thumb on the back, bend the head downward so as to make a sharp angle where the skull joins the vertebral column. With the right hand insert a needle, preferably one with the point in the form of a lancet through the skin into the foramen magnum. Push the needle forward into the brain, rotating the needle.

c. Place the pithed frog in the dissecting dish ventral side up, open the abdominal cavity in the usual way and remove the viscera, so as to expose the spinal nerves. Remove the skin from the hind legs, being careful not to injure the muscles or nerves.

Stimulate the spinal nerves of the frog where they leave the vertebral column and enter the abdominal wall, by placing both terminals on one nerve. Begin with the anterior nerves and work gradually posterior, stimulating the nerves in the order in which they occur.

QUESTION: Record as accurately as you can the result of stimulating each spinal nerve.

Finally pay particular attention to stimulating the sciatic nerve and observe accurately the changes which occur in the gastrocnemius muscle.

QUESTION: So far as you can observe does it change in volume?

E. The Central Nervous System of Man.

a. Examine a model or chart of the human spinal cord. Note its length, shape, and the origin of the spinal nerves.

QUESTION: What relation do the roots of the spinal nerves bear to the vertebrae?

b. Examine a model or chart of the human brain. Identify the following parts: *medulla oblongata*, which connects with the spinal cord, *cerebellum*, *cerebral hemispheres*, with their numerous *convolutions*, *olfactory bulb*.

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Question: Compare the size of these parts in the frog and man in the following table.

Part	Frog	Man
Medulla oblongata		
Cerebellum		
Cerebral hemispheres		
Olfactory lobes or bulbs		

11. The Sense Organs

A. The Olfactory Sacs of the Frog. Cut through an external naris and notice that it leads into a cavity, the olfactory sac.

B. The Eye of the Frog. With scissors cut round the eyelids so as to expose the eyeball. On the median surface of the eyeball notice the *eye muscles* and in the center of them the white round *optic nerve.* Cut these and take out the *eyeball.* Cut through the eyeball from its outer to its inner side, noticing as you do so the transparent *cornea*, the dark *iris*, and the hard crystalline *lens*, and at the back or internal side the *retina.* This is easily torn loose from the *choroid* and *sclerotic* coats, the latter of which forms the rigid portion of the eyeball.

Question: Where does the optic nerve enter the eye?

C. Observations on the Human Eye.

a. Look into a mirror and move the eyes about.

Question: When the right eye is moved to the right in what direction does the left eye move?

The eyeballs are moved by the eye muscles. That the eyes are able to move together and both keep an object in view is due to co-ordination, a process which occurs in the brain whenever a number of muscles act together.

b. Place the right hand over the right eye so as entirely to exclude the light from it. With the left eye look at some bright object, e.g., the sky, a bright piece of paper, etc., for two or three minutes. Then quickly look in the mirror with both eyes and compare the sizes of the pupils. Watch the pupil of the right eye and see if it changes in size. You have already observed that the size of the pupil is determined by the iris.

Question: What changes occurred in your right iris during the experiment?

Question: Were they voluntary or involuntary?

Question: Were you conscious of them?

c. On a piece of white paper or cardboard place two small crosses four inches apart. Cover your right eye with your right hand and hold the paper about twelve inches from your left eye. Look fixedly at the cross on the right and move the paper slowly back and forth until the cross on the left disappears. The cross on the left disappears when its image falls on the retina where the optic "nerve" enters the eye, i.e., the "blind spot."

Question: How far was the paper from the eye when the blind spot became apparent?

d. Examine a model or chart of the eye and identify: *pupil, iris, conjunctiva, lacrimal gland, muscles of the eyeball,* and in a longitudinal section the *sclerotic, choroid,* and *retinal coats,* the *lens,* the *aqueous humor,* and the *vitreous body.*

Question: Trace a ray of light through the eye from the exterior to the retina.

D. The Ear of the Frog.

a. Cut through the tympanum into the cavity of the *middle ear.* Look for a small rod of bone, the columella, attached to the center of the tympanum and connecting it with the *inner ear,* which lies in the bony auditory capsule of the skull and cannot be easily dissected in the frog.

b. The Human Ear. Examine a model or chart of the human ear. Identify the three parts, *external, middle,* and *inner ear.* Identify the tympanum and the three bones, the *malleus, incus,* and *stapes,* which transmit the vibrations of the tympanum to the inner ear. In the inner ear identify the *cochlea, utriculus sacculus,* and *semicircular canals.*

Question: Trace the path followed by the sound vibrations from the external ear to the cochlea.

Question: What relation do the planes of the semicircular canals bear to the head?

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XVIII. EMBRYOLOGY

1. Early Development of the Starfish

A. Study a prepared slide or a series of prepared slides showing starfish eggs in various stages of cleavage. Find an unfertilized egg which will not have undergone cleavage. Identify the *vitelline membrane, cytoplasm,* containing yolk granules and the *nucleus.* Next find eggs which are in the two-cell, four-cell, and eight-cell stages.

Question: In what direction are the planes of cleavage?

Question: Are the cells of equal size?

Find eggs in the later stages of cleavage.

Question: Are the eggs after cleavage as a whole greater in size than the egg before cleavage?

Draw a mature undivided starfish egg, 20 mm. in diameter.

Draw eggs in the two-celled, four-celled, eight-celled, and sixteen-celled stages to the same scale.

B. Obtain a prepared slide showing starfish eggs in the *blastula stage.* Identify the central cavity or *blastocoel.*

Question: How many cells thick is the layer of cells surrounding the blastocoel?

Draw a blastula on the same scale as the egg.

C. Obtain a prepared slide showing starfish eggs, which have developed into the *gastrula stage.* Identify the invaginated endoderm forming the *enteron* which is in communication with the exterior by the *blastopore.* Distinguish between *ectoderm* and *endoderm.*

Question: Can you recognize any difference in the size of the cells?

Draw a gastrula on the same scale as the egg.

2. The Development of the Frog

A. The *early development* of the frog is most conveniently studied on eggs which have been preserved and in which the black pigment of the animal pole has been bleached to a lighter color (see Appendix) so as to make the cleavage furrows more easily seen. Each stage should be studied individually in a watch glass containing a little water and examined with a hand lens. Do not touch the eggs with a needle or other sharp instrument. They can be moved about or turned over with the corner of a piece of paper.

a. The Unfertilized Frog's Egg. For this study, the egg should be still surrounded by its coats of jelly and be unbleached. Note the three layers of *jelly,* a thick *outer layer,* an almost equally thick *middle layer,* and a thin *inner layer* closely applied to the egg.

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Question: What functions does the jelly perform in the economy of the embryo?

Note the darkly pigmented *animal pole* and the light colored *vegetal pole*.

Draw a side view of an unfertilized egg showing the *layers* of *jelly*, making the total diameter 40 mm.

b. Study with the hand lens a bleached egg in the *two-celled stage*.

Question: Over which part of the egg are the cleavage furrows deepest?

Draw a view of the egg from the animal pole making the diameter 30 mm.

c. Study an egg in the *four-celled stage*.

Question: What relation does the second cleavage furrow bear to the first?

Draw **a view of the animal pole on the same scale as the previous drawing.**

d. Study an egg in the *eight-celled stage.*

Question: What relation does the third cleavage furrow bear to the other two?

Question: To which pole of the egg is the third cleavage furrow nearest?

Draw a side view of the egg showing all the cleavage furrows on the same scale as above.

e. Study *later cleavage stages.* Count the number of cells in each stage.

Question: Where are the largest cells formed?

Question: Where are the smallest cells formed?

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Draw as many stages as you have been able to identify on the same scale as the earlier stages.

f. Blastula. By the time the development has reached the blastula stage the cells of the animal pole are so small as scarcely to be distinguished with a hand lens. With a safety razor blade cut through the middle of the egg from the animal to the vegetal poles and examine the cut surface with a hand lens. Note the *blastocoel.*

QUESTION: Does it lie nearer to the animal or the vegetal pole?

Draw a view of the cut surface of the blastula on the same scale as the other stages.

g. Early Gastrula. Observe the *crescentic groove* between the pigmented and unpigmented portions of the egg. The middle of this groove marks the posterior of the future embryo.

Draw a posterior view of an early gastrula on the same scale as your other drawings.

h. Late Gastrula or Yolk Plug Stage. The crescentic groove has become a circular groove separating a central light-colored *yolk plug* from the surrounding pigmented part.

Draw a late gastrula stage oriented in the same way as the early gastrula and on the same scale.

B. Development into the Tadpole.

a. Stage with *open neural tube.* The yolk plug has now disappeared within the embryo and its position is marked only by a small pin hole-like opening, which will become the *anus.* Extending anteriorly from this point are two diverging ridges, the *neural ridges.* Between the neural ridges is the *neural groove.*

Draw a dorsal view of the embryo on the same scale as before.

b. Stage with Closed Neural Tube. The neural ridges have now grown over the neural groove forming a hollow *neural tube.*

Draw a dorsal view of a closed neural tube stage showing the fused neural ridges, on the same scale as before.

c. Stage with External Gills. The embryo has now hatched from the egg as an elongated fish-like larva, with indications of a head and tail. Note the *external gills.*

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Question: What is their position?

Draw a side view of the larva on the same scale as before.

d. Young Tadpole. The gills have now become enclosed in a gill chamber by an overgrowth of skin from the side of the head. The larva has now the appearance of a small tadpole with a *mouth, nostrils,* and *eyes.*

Draw a side view of the young tadpole on the same scale as before.

3. DEVELOPMENT OF MAN

A. If available examine human or other mammalian embryos of different ages and one to which the *placenta* is still attached. Identify the external parts of the embryo and the *umbilical cord.*

Question: Where is the umbilical cord attached to the embryo?

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XIX. HEREDITY

1. MUTATIONS

A. Examine individuals from mutant stocks of the fruit fly, Drosophila, either alive and anesthetized, or in prepared slides, and compare with normal individuals.

Fill in the following table.

	NAME OF MUTATION	PRINCIPLE VARIATION OR VARIATIONS FROM THE NORMAL
1.		
2.		
3.		
4.		
5.		

B. If available examine mutations in other animals and plants. The term mutation is now applied to any hereditary condition which obeys Mendel's laws. The origin of many hereditary conditions is unknown, but when they obey Mendel's laws they are called mutations.

2. MENDEL'S LAWS

A. A Simple Cross. Examine an ear of corn with normal (white) grains and one with grains showing the mutation purple.[1] Purple is a dominant character which affects the endosperm, and is designated by Pr. Its recessive allelomorph, white, is designated by pr. When a white grain from a plant of a pure strain is grown and its flowers are pollinated by pollen from a plant grown from a grain from a pure purple strain the resulting grains which represent the F_1 generation are all purple, this being the dominant character. Examine an F_1 ear.

When these (heterozygous) purple grains are planted and self-fertilized or interbred, the F_2 grains which result are of two kinds, purple and white in the ratio 3:1. Both purple and white grains occur on the same ear and by counting the numbers of purple and white grains the ratio in which these two types occur in the F_2 can be determined.

Fill in the following table for an F_2 ear.

NUMBER OF GRAINS		RATIO	
Purple	White	Purple	White

B. A Cross Involving Two Independent Characters. Examine an ear of corn in which the grains show the characters purple, Pr, and starchy, Su, (smooth, opaque seeds) and examine another ear in which the grains show the recessive characters white, pr, and sweet or sugary

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[1] Any other pair of available characters may be used, e.g., Starchy (dominant) and sweet, Red (dominant) and white.

(wrinkled, translucent seeds), su.[1] Grains from these ears may be used as the parents for a cross.

p Pr,Pr,Su,Su (purple starchy) x pr,pr,su,su (white sweet)

When a purple starchy grain (Pr,Pr,Su,Su) is planted and produces flowers the gametes formed are all Pr,Su; and when a white sweet grain (pr,pr,su,su) is planted and flowers the gametes are all pr,su. When the two plants are crossed the F_1 grains all appear purple and starchy.

F_1, Pr,pr,Su,su

When plants are grown from these F_1 grains, four kinds of gametes are formed.

F_1 Gametes: Pr,Su. Pr,su. pr,Su. pr,su

Fill out the following diagram showing how these gametes may unite in fertilization to form different types of F_2. In each square indicate genotype and phenotype.

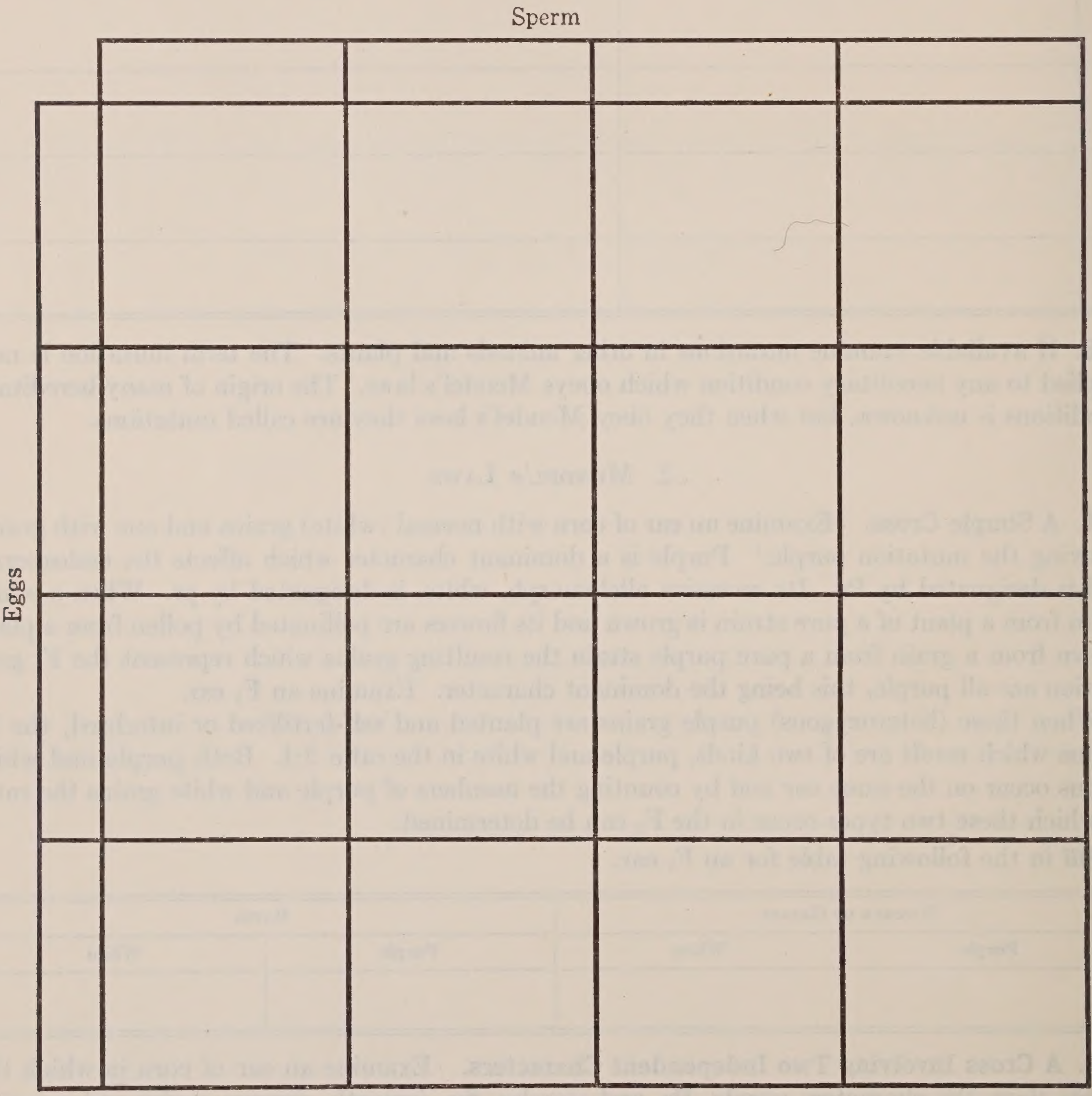

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Diagram Showing How Gametes May Combine in a Cross Involving Two Independent Characters

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[1] A number of other characters are available and may be used in place of those above.

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Fill in the following table for the F_2 phenotypes.

	COUNT OF GRAINS IN EARS	IDEAL RATIO	RATIO FOUND
Purple starchy			
Purple sweet			
White starchy			
White sweet			

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XX. A SURVEY OF THE ANIMAL KINGDOM

1. Phylum Protozoa

Examples of each of the four classes have been considered in this outline.

1. Sarcodina—Amoeba.
2. Mastigophora—Euglena, Volvox.
3. Infusoria—Paramecium.
4. Sporozoa—Plasmodium.

Examine under a low power a prepared slide containing shells of Foraminifera. These shells are secreted by amoeba-like animals belonging to the Sarcodina.

Question: What do these shells resemble?

2. Phylum Porifera

A. If not already studied examine a specimen of Grantia.

Question: What kind of symmetry does it possess?

With a hand lens locate the *osculum* at the free end and on the sides the *incurrent pores.* Water passes through these pores into a central cavity and out through the excurrent opening.

B. Examine under the low power of the microscope a slide containing sponge *spicules.*

C. Tease out a small piece of a bath sponge and examine on a slide under the low power of the microscope. Note the fibres of *spongin*, a substance which is chemically related to silk.

Question: State the characteristics which distinguish the Porifera.

Question: Are sponges actively moving animals?

Question: Where do sponges occur? (To be answered from your reading.)

3. Phylum Coelenterata

A. Class Hydrozoa.

a. The following examples of this class have already been considered in this outline. Hydra, p. 91, Obelia, p. 95, and Gonionemus, p. 97. Examine any of these which you have not already studied.

QUESTION: Compare these three forms as regards mode of life, whether free swimming or attached, whether solitary or colonial.

b. Physalia. Examine a specimen of Physalia (Portuguese Man-of-War). Note the large *float* with the sail-like *crest.* From the float hang down into the water a variety of cord-like and ribbon-like structures. These are polyps differentiated to perform different functions.

B. Class Scyphozoa. Examine a specimen of Aurelia. The animal is umbrella-shaped. Corresponding to the handle of the umbrella is a large lobed structure, the *manubrium,* in the center of which is the *mouth* opening into the *gullet,* which leads into a rectangular "*stomach.*" Numerous branched *radial canals* lead from the stomach to a circular canal near the margin of the umbrella. The gonads lie in gastric pouches connected with the stomach. They are light pink or purple in the living animal. The eggs or sperm pass out through the gullet and mouth. Eight cyst-like organs believed to be for detecting the animal's position with regard to the vertical (i.e., equilibrium) are located on the margin of the umbrella among the tentacles. The Aurelia is a free swimming marine animal.

QUESTION: Compare Aurelia and Gonionemus.

C. Class Anthozoa.

a. Examine a sea-anemone. A common genus on the East Coast is Metridium. Note the cylindrical shape of the animal, with a *basal disc* at one end and numerous hollow tentacles at the other. In the center of the rings of tentacles is the *mouth.* The internal structure is well seen in an animal which has been bisected longitudinally. The mouth leads into a *gullet* extending about half the length of the animal and opening into the *coelenteron.* From the gullet to the body wall extend numerous *mesenteries.*

b. Examine the skeleton of a coral and note the spaces in which the polyps live.

QUESTION: State whether the coral you examined is a solitary or colonial form.

4. PHYLUM CTENOPHORA

Examine a ctenophore. Pleurobrachia, the sea walnut, is a common form on the Atlantic Coast. Note the eight rows of *combs* or ciliated bands and the pair of *tentacles* (often partly or entirely torn off in preserved specimens) which make the animal *bilaterally symmetrical.*

5. PHYLUM PLATYHELMINTHES

A. Class Turbellaria. If not already studied under Section XIII-1, observe a living planarian in a watch glass under the hand lens and note size, shape, and movement. Distinguish anterior, posterior, dorsal, and ventral. Note the paired eyes.

QUESTION: What kind of symmetry does the planarian possess?

Place a small piece of meat or other food in the watch glass and watch for the protrusion of the *pharynx*.

B. Class Trematoda.

a. Study a prepared slide of the liver fluke, *Fasciola hepatica*, or some other trematode, and identify the *suckers*, mouth, and digestive cavity. See p. 99.

b. If available study prepared slides of cercaria.

QUESTION: From your reading in the textbook briefly outline the life-cycle of the liver fluke.

QUESTION: What peculiar features of a parasite does Fasciola illustrate?

C. Cestoda.

a. Examine a specimen of one of the species of Taenia or some other common tapeworm. Note the division into *proglottids:* the *head* or *scolex* if present will be so small as to be scarcely visible with the naked eye. See p. 100.

b. Study a prepared slide of a scolex and observe the hooks.

QUESTION: Is there a mouth opening?

QUESTION: What peculiar features of a parasite are illustrated in the tapeworm?

c. Study a prepared slide of a ripe proglottid. Most of the interior is occupied by the reproductive organs and eggs. See p. 101.

QUESTION: Do you find any evidence of a digestive system?

D. Classification.

QUESTION: State the characteristics of the Platyhelminthes as a group.

QUESTION: Distinguish between the three classes of flatworms.

6. PHYLUM NEMATHELMINTHES

A. *a.* If not already studied under Section XIII–2, study a specimen of Ascaris, the horse tapeworm. Identify at the straight, blunter end the *mouth*, and at a short distance from the other pointed and curved end, the *anus*.

b. Study a specimen which has been opened by a longitudinal slit and identify the *body cavity*, *digestive tube*, and *reproductive organs* (see p. 103).

QUESTION: What characters of the roundworms indicate an advance beyond the flatworms?

B. If available study prepared slides of *Trichinella* (the trichina worm) and *Necator*, the American hookworm.

QUESTION: From your reading in the textbook briefly outline the life histories of these roundworms.

7. INVERTEBRATES OF UNCERTAIN SYSTEMATIC POSITION

A. Nemertinea. Examine a specimen of Cerebratulus. Note size, shape, and color. Nemertines are mostly marine and resemble planarians in general form, mode of life, and in having a protrusible pharynx, but differ from them in having a blood vascular system and an anus.

B. Chaetognatha. Examine a specimen of Sagitta, the arrowworm. Note size and shape. These animals have a mouth, alimentary canal, and anus. Also a well developed nervous system and sense organs. They are all marine.

C. Rotifera. Examine a drop of water from a culture of rotifers, under the low power of the microscope. Locomotion is chiefly by means of cilia arranged on a disc at the anterior end.

Posterior to the disc the body is covered by a shell-like cuticle. The anatomy of these minute creatures is quite complicated and includes mouth, digestive tract, anus, coelom, excretory organs, and muscular and nervous systems. They are quite common in fresh-water ponds.

D. Bryozoa, or moss animals, are nearly all colonial and in this respect resemble a hydrozoan such as Obelia, but the internal anatomy of the individuals is more complicated. Most of them are marine, but there are a few fresh-water forms. Examine a portion of a colony on a prepared slide. A thickened cuticle supports the colony and each individual lies in a cup-shaped structure called a zooecium. From the rim of the cup in life projects a crown of tentacles. There is a U-shaped digestive tract with mouth and anus, and a true coelom.

E. Brachiopoda. Examine a specimen of *Lingula*, the lamp-shell. Note the bivalve shell resembling that of a mollusk. The internal anatomy of these animals is, however, very different from that of a mollusk and the valves are dorsal and ventral with regard to the body whereas those of a bivalved mollusk are right and left.

8. PHYLUM ECHINODERMATA

A. Class Asteroidea (Starfishes). If not already studied, examine a starfish. Note the shape of the body.

QUESTION: Is the skeleton on the outside or is it covered by a soft tissue?

Note the dorsal and ventral surfaces, the latter distinguished by the ambulacral grooves. Identify the mouth and anus, and the tube feet. Examine one of the latter with a hand lens.

QUESTION: What kind of symmetry is possessed by the starfish?

B. Class Ophiuroidea (Brittle Stars). Examine an example of this class.

QUESTION: Is there a line of demarcation between the disc and the arms?

C. Class Echinoidea.

a. Examine a sea urchin.

QUESTION: What is the shape of its body?

Locate the mouth and anus. With a hand lens look for tube feet among the spines.

b. If available, examine a sand dollar and compare it with a sea urchin.

D. Class Holothurioidea (Sea Cucumbers). Examine a sea cucumber.

QUESTION: Is there a rigid skeleton?

There are small plates imbedded in the body wall but they are not fitted together and do not form a rigid structure. Locate the mouth and anus. From the latter the *respiratory* organ may project. Look with a hand lens for tube feet.

E. Class Crinoidea (Sea Lilies). If available, observe one of these. Note the plume-like tentacles. The mouth and anus will probably not be visible. Note the skeleton composed of plates similar to those of the starfish and sea urchin.

F. Characters of the Phylum. Go over the specimens and notice that each is radially symmetrical with five radii of symmetry.

QUESTION: State three characteristics of the Phylum Echinodermata, the presence of which can be determined in an external examination.

QUESTION: Are the echinoderms actively moving animals?

9. PHYLUM ANNELIDA

A. Polychaeta. Examine a specimen of Nereis, the sand or clam worm.

QUESTION: Approximately how many segments are there?

Note the differentiation of the *head*, the presence of *tentacles* and *eyes* and the lateral expansions called *parapodia* with numerous setae. Most Polychaetes are marine animals.

B. Oligochaeta. If you have not already studied Lumbricus, the earthworm, examine a living or preserved specimen. Note division into segments, anterior mouth, posterior anus, absence of parapodia, but presence of setae.

QUESTION: Compare the anterior end of the Lumbricus with the anterior end of Nereis.

Most Oligochaetes are either terrestrial or fresh-water animals.

C. Hirudinea. Examine a leech. Note the anterior mouth and posterior sucker. Most leeches are ectoparasites living on the blood of fresh-water, terrestrial, or marine animals.

D. Characteristics of the Phylum.

QUESTION: State three distinctive characteristics of the Phylum Annelida.

10. PHYLUM MOLLUSCA

Five classes of mollusks are distinguished.

A. Class Amphineura. Examine a *chiton.* Note the shell composed of eight calcareous plates, and the flat foot by which the animal adheres to rocks on the seashore.

QUESTION: What kind of symmetry does the animal possess?

B. Class Gastropoda.

a. Examine a *snail.* Note the asymmetrically coiled shell, respiratory opening, foot, and tentacle.

b. Examine a *slug.* Note absence of shell, opening to respiratory chamber, foot, tentacles.

QUESTION: What kind of symmetry does the animal possess?

C. Class Scaphopoda. Examine a specimen of Dentalium, a tooth shell. Note shape of shell.

D. Class Pelecypoda. The clam (see p. 137) is an example of this class. If available examine other examples such as the oyster and scallop.

QUESTION: What kind of symmetry do the animals possess?

E. Class Cephalopoda. Examine an *octopus* or a *squid.* Note the well developed head with eyes and tentacles surrounding the mouth. Posterior to the tentacles is the funnel-shaped siphon and behind it a slit-like opening. These open into a cavity, the mantle cavity. The animal propels itself backwards by taking water into the mantle cavity through the slit-like opening and squirting it out through the siphon. It is able to swim forward by moving its lateral fins and to crawl with its tentacles.

QUESTION: List the characters which are common to the different groups of mollusks.

11. PHYLUM ARTHROPODA

A. Class Crustacea, with a few exceptions aquatic animals which breathe by means of gills and have a segmented body in which the segments are grouped into head, thorax, and abdomen or into a cephalothorax and abdomen. Two groups of crustacea are distinguished.

Group Entomostraca, small crustacea with a more primitive organization than the next group.

a. Examine a specimen of a copepod such as Cyclops. Note the jointed appendages and the division of the body into head, thorax, and abdomen, the two latter segmented.

Question: Compare the segmentation of a copepod with that of an earthworm.

b. Examine a specimen of a water flea such as Daphnia. Note the carapace, which extends from the dorsal side, forming a structure resembling a bivalved shell. The small abdomen is bent anteriorly and is enclosed by the carapace. The large antennae are used in swimming.

Question: Compare a water flea with a copepod.

c. Examine a barnacle such as Lepas, or Balanus. In these animals the carapace becomes attached to rocks, other animals, ship bottoms, etc., and forms a hard shell.

Question: How must this animal obtain its food?

Group Malacostraca.

a. Examine a sow bug, Oniscus. This animal is terrestrial, living in moist places under stones. It breathes by means of gills. Note the segmentation of the body. It is divided into head, thorax, and abdomen, the seven large free segments making up the thorax.

Question: Is there a carapace covering the thorax?

b. Examine a fresh-water shrimp, Gammarus. Note the laterally compressed body and the posteriorly directed springing feet.

Question: Is there a carapace?

c. Examine a shrimp, such as Palaemonetes. Note the division of the body into cephalothorax and abdomen, long antennules and antennae, the walking legs and the swimming legs.

Question: Is there a carapace? How many pairs of walking legs are there?

d. If not already studied, examine a crayfish or a lobster. Note the cephalothorax and abdomen, the walking legs attached to the cephalothorax, and the swimming legs attached to the abdomen.

Question: Is there a carapace? Are the eyes stalked?

B. Class Myriapoda.

a. Examine a millipede. Note the shape of the body and its division into rings, each of which probably represents two segments.

Question: How many pairs of legs are attached to each ring?

b. Examine a centipede. Note the antennae and the first pair of legs, which are modified to form poison claws. The divisions of the body are segments.

Question: How many pairs of legs are attached to each segment?

Question: What are the characteristics of the Myriapoda?

C. Insecta. Insects are characterized by the possession of three pairs of legs.

a. Order Aptera. Examine a "fish moth," not a moth at all but a very primitive type of insect. Note the segmentation of the body, the antennae, and the three pairs of legs.

Question: Are wings present?

b. Order Orthoptera. Examine a grasshopper or a cockroach. Note the biting mouth parts and the two pairs of wings.

Question: How do the fore wings differ from the hind wings?

c. Order Lepidoptera. Examine a butterfly or a moth. Note the antennae, three pairs of legs, and the sucking mouth parts.

Question: How do the wings differ from those of a grasshopper or a cockroach?

d. Order Diptera. Examine a house fly or a mosquito. Note the three pairs of legs and the mouth parts of the house fly adapted for lapping or those of the mosquito adapted for piercing and sucking.

Question: How many pairs of wings?

e. Order Coleoptera. Examine a beetle. Note the six legs, the biting mouth parts, and the two pairs of wings.

Question: How do the fore wings differ from the hind wings?

f. Order Hymenoptera. Examine a wasp or a bee.

Question: How does your specimen differ from a fly?

D. Class Arachnida.

Examine a spider. Note the absence of antennae, the division of the body into cephalothorax and abdomen, and the absence of wings.

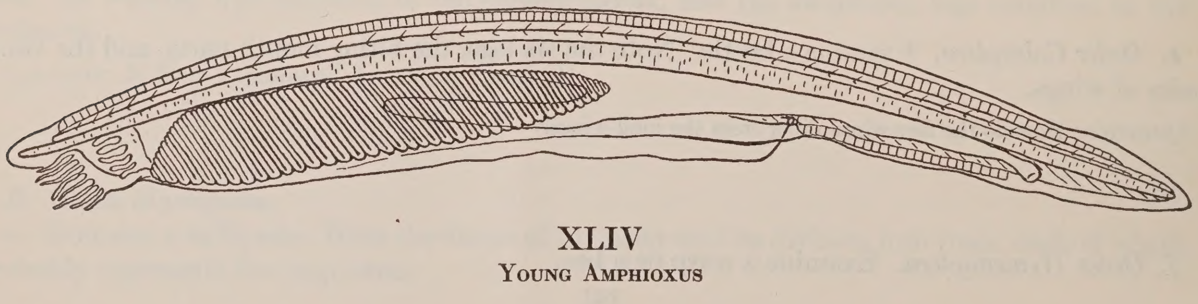
Question: How many pairs of legs are there?

12. Phylum Chordata

A. Protochordata (not a subphylum but a convenient term which includes three different subphyla).

a. Examine a prepared slide of a young *amphioxus* under the low power of the microscope. Note the fish-like *shape of the body*, the *anterior end* with a circle of *tentacles* surrounding the funnel-shaped *oral hood*, at the bottom of which is the *mouth*, the *posterior end* with the *caudal fin*, on the left side of which is the *anus*, and the absence of paired fins. The internal anatomy can now be studied. The *notochord* appears as a light colored striated rod in the dorsal region, extending the entire length of the animal, and tapering toward either end. The striated appearance is due to the peculiar disc-shaped cells of which the notochord is composed. Immediately dorsal to the notochord is the *neural tube*, also tapered at either end and extending the entire length of the body. On the ventral side of the neural tube, especially in the anterior region, are numerous small dark objects, which have been shown to be sensitive to light (Amphioxus has no eyes). Lateral to the neural tube a series of diagonal lines can be seen, which mark the divisions between the muscle myotomes or somites. The digestive system extends as a tube from the mouth to the anus. The mouth opens into a large *pharynx*, which leads into a straight *intestine*. Opening into the intestine and extending forward on one side of the pharynx is the *liver diverticulum*. The intestine lies in a *coelomic cavity*. The respiratory system consists of a series of *gills* and slit-like *gill clefts* opening from the pharynx into an *atrial* cavity, which in turn opens to the exterior by an *atriopore* somewhat anterior to the anus. Water is taken in through the mouth, passes through the gill clefts into the atrial cavity, and out through the atriopore. The excretory system, which consists of a series of nephridia leading from the coelom to the atrial cavity, requires special methods for its study. The circulatory system, which consists of a dorsal and a ventral vessel, with vessels connecting these in the pharynx and intestine, cannot be conveniently studied in the specimen.

Label on the printed outline the structures observed in Amphioxus.



XLIV
Young Amphioxus

Name__________________________________ Section______________________ Date________

b. Compare Amphioxus with an Arthropod in the following table:

	ARTHROPOD	AMPHIOXUS
Skeleton		
Respiratory system		
Nervous system		

B. Subphylum Vertebrata.

a. Pisces (*the Fishes*). Examine a perch. Note the *shape of the body*, the *head, tail*, the *unpaired fins* (two *dorsal*, an *anal*, and a *caudal*) and the *paired fins* (*pectoral* and *ventral*), the *eyes* and the *mouth* limited by the *upper* and *lower jaws.*

QUESTION: Is there any evidence of external ears?

The *operculum*, or gill cover, is a bony flap which extends backward from the side of the head and covers the gills. Lift it up and note the *gills* and *gill clefts.*

QUESTION: With what cavity do the gill clefts communicate?

Note the scales with which the body is covered. These are bony scales developed in the dermis.

QUESTION: Are the scales covered with epidermis?

Examine a dissection or model of the internal organs of a perch. Identify *brain* and *spinal cord, vertebral column, body cavity, mouth, pharynx, gills, gill clefts, stomach, intestine, anus, liver, heart, reproductive organs.*

QUESTION: Where is the heart located with reference to the other organs?

b. Compare the Perch with Amphioxus.

STRUCTURE	AMPHIOXUS	PERCH
Body form		
Appendages		
Skeleton		
Respiratory system		
Digestive system		
Circulatory system		
Nervous system		
Excretory system		

c. Class Amphibia. Order Urodela. Examine Necturus, the mud-puppy, or a newt or salamander. Note the division of the body into head, neck, trunk, and tail, the mouth and eyes.

QUESTION: Is there an external or a middle ear?

In Necturus note the *gills* and *gill clefts*, absent in the adult newt or salamander. Examine the appendages and note their division into upper and lower leg, wrist or ankle, and foot.

QUESTION: How many toes on the fore feet? on the hind feet?

Order Anura (Tailless Amphibia, Frogs, and Toads). The frog has already been studied and may serve as an example of this order.

QUESTION: How does a frog differ from a urodel?

*Name*______________________________________ *Section*__________________________ *Date*_________

d. Class Reptilia, Order Chelonia (*Turtles and Tortoises*). Examine a turtle or tortoise. Note the division of the body into head, neck, trunk, which is enclosed between the carapace (dorsal) and the plastron (ventral), and tail. Note the *horny scales.* Examine the carapace of a turtle.

QUESTION: Do the horny outer scales correspond to the inner bony plates?

QUESTION: What is the relation between the ribs and the carapace?

Order Squamata (*Lizards and Snakes*). Examine a lizard. Note the division of the body into head, neck, trunk, and tail. Note the covering of horny scales.

QUESTION: State one easily recognized difference between a lizard and a urodel.

Examine a snake. Note the horny scales, absence of appendages. Locate the anus.

QUESTION: What proportion of the length of the snake is tail?

e. Class Aves (*Birds*). Examine the foot of a chicken or other bird and note the horny scales similar to those of a reptile. Examine a feather. Note the *vane*, or feathery portion, and *calamus* or quill. The vane is composed of a solid longitudinal axis or *rachis* from which *barbs* extend. Examine a portion of a feather under the low power of the microscope. The barbs are hooked together by fine barbules. A feather is in reality a specially modified horny scale. Examine the skeleton of the wing of a bird. Note the humerus, radius, ulna, the bones of the wrist and the three digits.

QUESTION: In what respects does a bird resemble a reptile?

f. Class Mammalia (*Mammals*). Examine a rat. Note the five regions of the body, the hair which takes the place of the horny scales of reptiles, the scales on the tail, the claws on the feet, the mammary glands, and the external ear. Examine a rat's tail with the hand lens and note the relation of the hairs to the scales. If alive note the body temperature.

QUESTION: State three characteristics which place man among the mammals.

1.

2.

3.

g. A Comparison of the Different Groups of Vertebrates. Fill out the following table.

	FISHES	AMPHIBIA	REPTILIA	AVES	MAMMALIA
Shape of body					
Head					
Neck					
Thorax					
Abdomen					
Tail					
Appendages Fore					
Hind					
Scales					
Feathers					
Hair					
Gills					
External ear					

h. Orders of Mammals.

Order Insectivora. EXAMPLE: a Mole.

QUESTION: How is this animal adapted to its mode of life?

*Name*___________________________________ *Section*______________________ *Date*________

QUESTION: Where are the eyes?

Order Chiroptera. EXAMPLE: a Bat.

QUESTION: How are the fore limbs modified for flight?

QUESTION: How many toes are there on the forelegs?

QUESTION: How long are they?

Order Carnivora. EXAMPLE: a Cat.

QUESTION: On what part of the foot does a cat walk?

QUESTION: Where are the canine teeth?

QUESTION: How are the teeth modified for flesh eating?

Order Rodentia. EXAMPLE: a Rat.

QUESTION: Compare the front teeth (incisors) with those of the cat.

QUESTION: What do the teeth of the rat indicate regarding its mode of life?

Order Ungulata. EXAMPLE: a Horse.

QUESTION: Compare the skull and teeth with those of the cat.

QUESTION: To what kind of diet are the teeth of the horse adapted?

Question: Compare the hind leg of a horse with that of a cat.

Order Primates. **Example**: Man.

Question: What structures in man correspond to the claws of a cat's feet?

Question: Compare the position of the eyes in a man and a cat.

Question: Compare the teeth of a cat and a man.

APPENDIX

Gum arabic solution. Make up three days before use.

Gum arabic	100 grams
Water	300 cc.

Oil emulsion.

Scott's emulsion	20 cc.
Water	1000 cc.

Lugol's solution.

Potassium iodide	6 grams
Iodine	6 grams
Water	1000 cc.

Yeast culture. Make up a few hours before needed. Add a quarter of a yeast cake to

Molasses	100 cc.
Water	900 cc.

Carmine suspension. Grind 10 grams carmine in enough water to make a paste, then dilute to 1000 cc.

Methyl green solution.

Methyl green	10 grams
Glacial acetic acid	20 cc.
Water	1000 cc.

Bleaching frog's eggs. To remove jelly from eggs, place in

Sodium hypochlorite, 10% sol.	1 part
Water	5 parts

Wash in water. Then bleach in hydrogen peroxide.

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